

**AN INVESTIGATION INTO THE READABILITY OF THE GRADE 10 PHYSICAL SCIENCE
TEXTBOOKS: A CASE STUDY**

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ABSTRACT

In her newsletter “Curriculum News, Improving the Quality of Learning and Teaching: Planning for 2010 and Beyond”, Mrs Angie Motshekga, MP, Minister of Basic Education, positions the textbook very definitely as central to the curriculum and states that it is one of the most effective tools through which to deliver the curriculum and support assessment.

Acknowledging the importance of the accessibility of textbooks for the South African classroom audience, this study has sought to investigate the readability of the chemistry section of grade 10 science textbooks. Readability research is concerned with the relationship between the textbook, the reader and the context in which the book is read; research supports the use of both classical quantitative measures and a qualitative cognitive-structural form of analysis to investigate this relationship.

The research design is a mixed method one where quantitative and qualitative data were collected simultaneously: the methodical application of selected readability formulae gave rise to quantitative data while the line-by-line textual analysis, tracing cognitive-structural aspects, and focus-group discussions with teachers gave rise to the qualitative data. The results of the merged data analysis were then interpreted together to provide a better understanding of the readability of the texts for a South African audience.

The results of the investigation reveal that readability is greatly impaired for a number of reasons, the primary one being a lack of articulation between the textbook writers/editors and the audience for which they are writing and preparing the texts. This is particularly reflected in the inadequate preparation of the material for the English Second Language reader, as certain textbooks are completely out of their reach.

Furthermore, this lack of articulation can be traced to the lack of time available for piloting the textbooks: an invaluable intervention in the process of textbook production.

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GLOSSARY

DoE	Department of Education
CAPS	Curriculum and Assessment Policy Statement
EC	Eastern Cape Province
EFA	Education For All
FET	Further Education and Training
FKRF	Fleish-Kincaid Readability Formula
GET	General Education and Training
IEA	International Association for the Evaluation of Educational Achievement
KA	Knowledge Area
LoLT	Language of Teaching and Learning
MLA	Monitoring Learning Achievement
NCS	National Curriculum Statement
OBE	Outcomes Based Education
OECD	Organisation for Economic Co-operation and Development
PIRLS	Progress in Reading and Literacy Study
RNCS	Revised National Curriculum Statement
SACMEQ	Southern and Eastern African Consortium for Monitoring Educational Quality
SA	South Africa
SASA	South African Schools Act
SD	Standard Deviation
TIMSS	Trends in International Mathematics and Science Study
UNESCO	United Nations Educational Scientific and Cultural Organisation
WC	Province
WM	Working Memory
WMC	Working Memory Capacity
WMS	Working Memory Space

CHAPTER 1

INTRODUCTION

School textbooks, having withstood criticism and extensive research as a teaching tool, remain one of the most important instruments of teaching and learning. The combination of factual content and pedagogical approaches present a systematic process of learning which shape the development of learning abilities and behaviour patterns in learners (Hummel, 1988).

Furthermore, educational research repeatedly underscores the role of the textbook as one of the most effective tools through which to deliver the curriculum and support assessment (Altbach & Kelly, 1988; Farrell & Heyneman, 1989). Reynolds (1997), in a South African study of what guides 'teacher's choice' of textbooks, comprehensively sums up the role of the textbook. Reynolds (1997) notes that a good textbook frees a teacher to concentrate on teaching rather than developing materials and also provides valuable support to the learner when engaging with homework and independent learning. A further and often underestimated value of the textbook is providing 'catch up' for learners who have missed lessons (Reynolds 1997:46).

In essence, the textbook is an aid to both the teacher and the learner; it reduces the amount of time teachers have to spend on preparation and reinforces the effectiveness of contact time with learners. The textbook continues the lesson outside the bounds of the classroom and is an invaluable support to the learner during the periods of independent engagement with the subject content. Research has shown that it is one of the strongest methods for fostering life-long learning (Hummel, 1988), one of the goals underpinning education in South Africa.

In *Curriculum 2005*, the new South African curriculum introduced in 1998, the role of the textbook was subordinated to the idea that teachers should develop their own learning materials. Teachers were encouraged to 'dip in and out' of textbooks and to develop their own worksheets and other learning and teaching support materials (LTSM) (DoE, 2009: 52). Working systematically through a single book was discouraged and instead a wide range of source material was recommended.

More recently, however, and following proposed changes in the curriculum and subject content documents, the National and Provincial Departments of Education (DoEs) have taken positive steps to encourage the wide use of textbooks. In her proposed 'Action Plan to 2014', Mrs Angeline Motshekga, Minister of Basic Education, states that one of the educational goals is to "ensure that every learner has access to the minimum set of textbooks and workbooks required according to national policy" (Government Gazette, 2010:6).

A change in curriculum necessitates both the re-training of the teaching corps and the redesign of textbooks to facilitate its implementation (Seguin, 1985). Seguin further asserts that the timing of each step of the transformation process is critical to its success and he allows for a minimum of two years between the gazetting of revised curriculum content and the finalisation of textbooks supporting that curriculum so that "the latter faithfully reflect the objectives and content of the programmes" (Seguin, 1989:10).

Seguin further notes the importance of trialling draft versions of the textbooks by teachers in classrooms before their publication. This process of trialling forms the basis of textbook evaluation, and he recommends that this be implemented systematically by qualified teachers in a representative sample of the classes for which the texts are intended.

The trialling of textbooks serves a number of intervention functions: it precedes their final publication ensuring a healthy financial investment in the final publication; it provides a sound pedagogical tool that can be trusted in the classroom context; and it facilitates a smooth implementation of the curriculum (Seguin, 1989:60).

However, the design of the implementation process in South Africa precludes a trialling period and so textbook development and publication is fraught with the following frustrations:

- Unrealistically short textbook production timeframes, set by the DoE, play a significant role in how little time is available to commission, write, edit, review and check manuscripts. Currently the content of a number of subjects is being revised and the *Curriculum and Assessment Policy Statement (CAPS)* document that will guide the textbook authors and publishers, is to be made available in January 2011, with the deadline for submission of draft copies of the textbooks set for mid-year 2011.
- Publishers are under extreme time pressure to identify and commission suitable authors to write textbooks to often rushed and inadequate curriculum documents. The Review Committee commissioned by the Minister of Education in 2009 cited the inadequate curriculum documents as a severe hindrance to teaching and learning during the implementation of the *National Curriculum Statement (NCS)* (DoE, 2009).
- Authors generally not trained to write for second language readers have to write to tight deadlines. As approximately 80% of the senior learners in South African schools learn in their second language, this disregard for the preparation of texts for these learners has serious repercussions.
- Editors (often specialist editors with little or no teaching or subject specialist training or experience) need to apply editing 'house rules' to meet DoE deadlines for manuscript submission. These editors have little time to acquaint themselves with second language teaching principles and the way these need to underpin manuscripts. The net result is textbooks produced to 'standardized' discourse and not tailored to meet the specific educational needs of the country, (as is advised by Seguin (1989)).

As a practising Mathematics and Science teacher, I experienced the implementation of the NCS in 2006 for grade 10 and the subsequent implementation in 2007 and 2008 of the NCS for grades 11 and 12. We had been informed that there were significant changes in our subject content and the new content was necessary to align the outdated South African

science curriculum with those of developed nations. In 2005, when we attended the compulsory training workshops for the NCS, no content document was as yet available and the assessment protocol was also vague.

2006 marked the beginning of a period of extreme uncertainty in the science teaching field in South Africa. The new Physical Science content was extensive and the familiar subject content had been aligned with the outcomes based principles underpinning the NCS. As no workshops were provided for rural teachers in the region where I taught, the textbook became the first point of departure in an attempt to interact with and to teach both new and familiar content.

However, the textbooks sent to the school were variable in their elaboration of the science content and their interpretation of the NCS Physical Sciences (Grade 10-12): Content Document. These limitations, coupled with the errors in answers to worked examples, fostered an immediate lack of confidence in the pedagogical value of the textbooks.

Furthermore, it was difficult to make choices regarding textbook selection as the time given for this task was limited by the deadlines which were necessary for publishers to produce the required number of textbooks ordered within the short time frame provided by the DoE. This, coupled with our lack of training and experience in selecting textbooks, led to incorrect choices being made. Indeed, some of my colleagues chose textbooks that proved unsuitable and the financial implications of replacing these were prohibitive.

The National Certificate results for the Physical Sciences were poor for both 2008 and 2009, the pass rate being 66% and 54% respectively. These results bear testimony to this period of uncertainty and the often inadequate learning and teaching support materials (LTSMs).

This context provides the background to my investigation into the readability of the grade 10 textbooks. Grade 10 was chosen as the focus for the study for two reasons: it is the year that marks the beginning of the final phase of secondary school education and is also the year in which learners engage for the first time with elective subjects. Thus in grade 10, learners are engaging seriously with the subject, Physical Sciences, for the first time.

A brief outline of the thesis follows:

In Chapter 2, the Literature Review, the theoretical framework that underpins the study is provided. The Literature Review is divided into four sections.

Section 2.1 deals with the classical readability paradigm: it describes readability formulae; their development; their credibility as a quantitative measure of first and second language readability; and their limitations.

Section 2.2 examines the cognitive-structural readability paradigm: the effect of the rhetorical structure of texts on readability; graphicacy and its enhancement of textual comprehension; the effects of prior knowledge activation; the 'seductive details' effect; and research into the cognitive demands which scientific text makes on the reader.

In Section 2.3, the Language of Science is examined: scientific vocabulary; non-technical vocabulary; logical connectives; the symbolic language of science; and finally, nominalization and the abstract nature of scientific discourse.

Finally, in Section 2.4 the literacy levels of South African grade 10 learners are discussed: the results of national systemic evaluations; international literacy assessments; the language policy in education in South Africa; and pertinent current South African education reviews.

The Literature review ends with a brief account of current research on textbooks in South Africa and what can be considered as 'best practice' in assessing the readability of science texts.

In Chapter 3, the Methodology chapter, the research design is described and justified. The Methodology chapter is divided into eight sections, 3.1 – 3.8, according to the different dimensions of this study that required decisions to be made, namely:

- Conducting the preliminary research;
- Choosing a mixed method design;
- Sampling techniques for qualitative and quantitative data gathering;
- Selecting qualitative data and a discussion of qualitative data analysis;
- Selecting quantitative data and a discussion of quantitative data analysis;
- Addressing validity threats; and

- Discussing ethical issues encountered in the research.

Chapter 4, the Findings, is divided into five sections, 4.1 – 4.5. Three textbooks, each forming a case-study, have been analysed, quantitatively and qualitatively; these findings are reported in sections 4.1 – 4.3. Section 4.4 reports on a quantitative analysis of the comprehension of non-technical vocabulary and finally, section 4.5 reports the findings of the focus-group discussions with teachers using the textbooks selected for evaluation.

Chapter 5, the Discussion of Findings, is divided into seven sections. In the first three sections, 5.1 – 5.3, the data analysis relating to the textbooks is discussed; in sections 5.4 and 5.5, the data analysis relating to the reader and the context in which the books are mediated is discussed. A brief summary of the findings concludes each section.

The final two sections, 5.6 and 5.7 deal with the recommendations and limitations of the study. In these, the final conclusions from this study are drawn; these include:

- What has been learnt from the study;
- The implications of the findings for teachers, education authorities, authors and publishers;
- The limitations of the study and suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

The review begins by addressing the concept of readability and defining it in the context of this study. This is followed by a comprehensive review of the history, development and theoretical base of the quantitative readability formulae from their inception at the turn of the last century, until today.

In some respects, the review of the readability formulae seeks to highlight both the strength of their objectivity as well as the lacuna created when relying on them as a sole measure of readability.

Thus the discussion continues with a review of the cognitive-structural paradigm of readability, as well as research in this area, and further describes the key theoretical resources which researchers within science education have developed whilst exploring the language of science and what makes it challenging.

Finally, attention is paid to the reader and more particularly, the second language reader. The research into the literacy of South African learners is then reviewed, together with pertinent current South African education reviews.

Chapter two concludes with a summary of what the literature on research into the readability of textbooks, and specifically science texts, elucidates as 'best practices' in research in this field of education.

2. A DEFINITION OF THE CONCEPT OF READABILITY

Dale and Chall (1949:1) define readability as the "sum total (including the interactions) of all those elements within a given piece of printed material" that affect how successfully a group of readers interact with it. "The success is the extent to which they understand it, read it at an optimal speed and find it interesting." This definition of readability, as an interaction between the text and the reader, is further extended by McLaughlin (1969), the creator of the SMOG readability formula. He argues that readability depends on the degree

to which a given class of people, characterized by their reading skill, prior knowledge and motivation, find certain reading matter compelling and comprehensible (DuBay, 2004:3).

Spache, too, focuses on the role of the reader, stating that “in the strictest sense of the term, a person cannot be said to be reading unless he also comprehends” (Spache, 1962: 61). He indicates that evidence supports the “belief that intellectual factors are important components of comprehension” (Spache, 1962:64) and further notes that as the number and complexity of concepts increase, so comprehension decreases. He states that reading materials are simplified only by both a reorganization of concepts as well as a simplification of the relationships among concepts presented.

Chall and Dale (1995:80) sum readability research as being concerned with the relationship between three variables. The first of these is the book or passage, “which is more or less readable depending upon its internal characteristics: language, organization and cognitive complexity.” They note the second variable as being the reader: “his/her reading ability, language, cognition, previous knowledge, interests and purposes for reading.” Finally there is the context in which the book is read: “whether the reader receives instructional help from a teacher or knowledgeable peers, and the degree and kind of comprehension expected – whether a gist, thorough knowledge, or critical reaction” (Chall & Dale, 1995:80).

Readability and the relationship between the above mentioned variables forms the basis of this research study and subsequently, the survey of the literature and research pertaining to readability which now follows, is distilled within this context.

2.1. THE CLASSICAL READABILITY PARADIGM

2.1.1. THE READABILITY FORMULAE – AN INTRODUCTION

Very simply, readability formulae are multiple regression equations in which the dependent variable (the value to be determined) is the predicted reading difficulty of a text and the independent or predictor variables are two or more directly measurable characteristics of the text, such as the number of letters per word and the number of words per sentence. To use one of the readability formulae, the independent variables in a piece of text are

measured, substituted into the selected readability formula, and a prediction of the text's difficulty is then expressed as a grade level, a cloze score, or a score on some set scale.

A number of formulae, termed the classical readability formulae, have been developed and some of the most respected of these, such as the Flesch (1948) and Dale-Chall (Dale & Chall, 1948), had their inception in the 1940s. For a time, during the 1980s, readability formulae, when viewed from the vantage point of psycholinguistic theories of reading, were criticized because of their seemingly a-theoretical nature and their validity being founded solely on text (Bruce, Rubin, & Starr, 1981; Rubin, 1985). Nevertheless, the formulae have survived and are still widely used on account of their consistently high predictive validity (Chall & Dale, 1995; Fry, 1989). They are an empirically valid means of measuring text difficulty.

To establish the validity of the formulae and also discuss the criticisms levelled against them, the classical readability paradigm is now reviewed.

2.1.2. DEVELOPMENT OF THE READABILITY FORMULAE – FOCUS ON SEMANTIC AND SYNTACTIC FACTORS

Sherman, as early as 1893, noted a relationship between the length of sentences and the period in which a particular piece of writing originated. The earlier periods were characterized by longer sentences: the average sentence length in pre-Elizabethan times was 50 words, whereas during the time Sherman was teaching, average sentence length had decreased to 23 words.

His work, published in *Analytically of Literature, A Manual for the Objective Study of English Prose and Poetry*, set the agenda for a century of research into readability by proposing that literature can be a subject for statistical analysis and that shorter sentences and concrete terms increase readability. He showed how individual writers are remarkably consistent in their average sentence lengths and this consistency was to become the basis for the validity of using samples of text rather than the complete text for readability prediction (DuBay, 2004:10). Most importantly he stressed the need to involve the reader by asserting that writing style was not “a thing of style merely, but must regard the expectations of the reader...” (Sherman, 1893:327).

Global educational trends and a changing demography, together with the growing use of scientific tools for studying and objectively measuring education problems, accelerated the development of readability formulae (DuBay, 2004; Chall & Dale, 1995).

Thorndike's *Teacher's Word Book*, published in 1921, was the first extensive listing of words in English by frequency and it provided teachers with an objective means for measuring the difficulty of words and texts and thereby laying the foundation of almost all subsequent research on readability that would follow.

Ojemann (1934), building on Thorndike's work, was the first to use adults to establish the difficulty of his criterion passages. In a series of multiple choice comprehension tests, he correlated six factors of vocabulary difficulty, and eight factors of composition and sentence structure, with the difficulty of his criterion passages. He reaffirmed Thorndike's word list but more importantly, noted that qualitative text factors, among them, abstractness, affect the readability of texts. Although he was unable to measure these qualitative factors numerically, he established that they could not be ignored (DuBay, 2004:15).

In 1935, Gray and Leary published a landmark study, *What Makes a Book Readable* (Gray & Leary, 1935). Their study attempted to discover what makes a book readable for adults of limited reading ability and their criterion included a significant number of samples, each of about 100 words, half of them fiction and the other non-fiction. They established the difficulty of these sections, by giving a reading-comprehension test, designed to test their ability to get the main idea of the passage, to a representative sample of more than 800 adults. The authors first identified 228 elements that affect readability and grouped them under the four headings of content, style, format and features of organization.

Gray and Leary found that content, with a slight margin over style, was the most important. Third most important, was format, and almost equal to it, 'features of organization' referring to chapters, sections, headings, and paragraphs that show the organization of ideas.

They were unable to measure content, format or organization statistically and so, while not ignoring the other three causes, Gray and Leary concentrated on 80 variables of style; 64 of which they could reliably count. They tested these elements rigorously, administering the tests to a wide adult sample. Each test included several passages and questions to determine how well they were understood by the subjects and subsequently, having a measure of the difficulty of each passage, Gray and Leary were able to see what style variables changed as the passages became more complex.

Of the 64 countable variables related to reading difficulty, those with correlations of .35 or above were of particular interest and although none of the variables studied had a higher correlation than .52, the authors realized that by combining variables, they could reach higher levels of correlation. However, because combining variables that were tightly related to each other did not raise the correlation coefficient, they needed to find which elements were highly predictive but not related to each other. Gray and Leary used the five variables listed below (Gray & Leary, 1935:115), to create a formula, which has a correlation of .645 with reading-difficulty scores.

1. Average sentence length in words: -.52
2. Number of different 'hard words': -.50
3. Number of first, second, and third- person pronouns: .48
4. Percentage of different words: .38
5. Number of prepositional phrases: -.35

An important characteristic of readability formulae can be noted from their findings: namely: that a formula that uses more variables may be only minutely more accurate but much more difficult to measure and apply than one using fewer variables.

Gray and Leary's work stimulated an enormous amount of effort to find the perfect readability formula by using different combinations of the style variables, but the two found to be most strongly associated with comprehensibility in classic readability formulae are vocabulary difficulty and sentence length (Chall, 1958; Klare, 1963; Lorge, 1938). Research eventually established that the semantic difficulty of vocabulary and the syntactic measure of average sentence length are among the best predictors of textual difficulty and by the 1980s there were approximately 200 formulae and in excess of a thousand studies

published on readability formulae, attesting to their strong theoretical and statistical validity (DuBay, 2004:2).

Various forms of the above two factors are included in most classic readability formulae with the stronger of the two being vocabulary, measured by either word difficulty or word length (Chall & Dale, 1995: 81).

The background to, and details of two of the oldest and arguably, the most valid of the formulae, are now briefly reviewed.

2.1.2.1. THE FLESCH READABILITY EASE FORMULA

Rudolf Flesch, a readability consultant, lecturer and teacher of writing at Columbia University was largely responsible in the 1940s for publicizing the need for readability (DuBay, 2004: 20). He published a revised formula in 1948 that used the number of syllables and the number of sentences for each 100-word sample. It predicts reading ease on a scale from 1 to 100, with 30 being 'very difficult' and 70 being 'very easy' (Flesch, 1974). His formula which correlates .70 with the McCall-Crabbs reading test, became the most widely used formula, as well as one of the most tested and reliable (Chall, 1958; Klare, 1963). In 1976 his formula was simplified and converted to grade level, now known as the Flesch-Kincaid Readability Formula (FKRF) (DuBay, 2004:49).

2.1.2.2. THE DALE-CHALL READABILITY FORMULA

The Dale-Chall readability was first formulated in 1948 and then later revised during the 1980s with the revised formula and added qualitative considerations published in 1995. Dale, together with Jeanne Chall, developed a list of difficult words and combined this variable with that of sentence-length to predict readability. Of all the readability formulae produced in the classic period, validations of this formula have produced the most consistent results, as well as having the highest correlations. In the 1970s the authors of the formula discussed the need to upgrade the difficult word list developed and also rerun validity checks on their formula. They commenced work during the 1970s and Dale-Chall Revised Formula was published for use in 1995 (Chall & Dale, 1995).

As reviewed above, formulae founded on both a vocabulary as well as a sentence factor, predict the comprehension difficulty of written text to a high degree of accuracy. Multiple correlations of these run from approximately .7 through to .9 with multiple choice or cloze comprehension tests. Researchers have tended to rely on the strong empirical findings to explain the importance of word and sentence factors and the traditional formulae work precisely because they are strongly grounded in theory – the combined theories of language and reading development (Chall & Dale, 1995:81). Semantic growth and syntactic development follow the patterns of cognitive development, and theory and research on language development underlie the consistent findings on the potency of word and sentence factors in readability measurement.

Chall, in her defence of classic readability formulae, added that at the height of their criticism, the Lexile Theory, a classic readability measure, was published in 1988 by a research group in Durham, North Carolina. Lexile Theory, a construct theory for reading comprehension hypothesizes that the comprehensibility of continuous prose is a function of two components: a syntactic component (the demands that comprehending a text places upon verbal short-term memory and the executive control component) and a semantic component (the familiarity of the words used in the text) (Chall & Dale, 1995:89). Chall argues that by using these two factors: word familiarity and sentence complexity, Lexile Theory brings readability back to the classic tradition.

2.1.3. LIMITATIONS OF THE CLASSICAL FORMULAE AND THE CRITICISMS LEVELED AGAINST THEM

Readability research initially focused on factors that could be measured numerically but researchers were aware of and continually acknowledged the influence of qualitative factors on the readability of texts. The first opponent of classical readability measurement was Taylor in 1953. He cited several difficulties with the classic readability formulae and argued that words were not necessarily the best measure of difficulty but rather how they relate to one another. He proposed using deletion tests called cloze tests for measuring an individual's understanding of a text. Cloze testing has been extensively researched (Treece, 1991) and is widely used, tending to complement conventional reading tests rather than the readability formulae (DuBay, 2004:27). According to Chall, this can probably be

attributed to the fact that cloze departed from arguably one of the most useful features of traditional readability formulae, namely estimating difficulty without relying on readers. Cloze requires a panel of readers to judge text difficulty (Chall & Dale, 1995:84).

Walter Kintsch also questioned the value of using the classic readability factors of word difficulty and sentence complexity and focused his attention on the cognitive and structural aspects of readability. He proposed to measure readability by measuring the number of propositions in a text (DuBay, 2004:31). In the early part of his work, he was quite critical of the readability formulae (Kintsch & Vipond, 1979), however, he eventually admitted that “these formulae are correlated with the conceptual properties of text” and that vocabulary and sentence length are the strongest predictors of difficulty (Kintsch & Miller, 1981:222). His work on coherence in a text was a further step in understanding qualitative factors affecting readability and he found that lack of coherence affects the comprehension of text for lower-grade readers.

Further critics of the formulae (e.g., Redish and Selzer (1985)) have complained that the readability formulae were developed for children’s literature and they were never tested or formulated for technical documents. The record shows, however, that popular formulae such as the Flesch Reading Ease and Kincaid formulae were developed mainly for adults and have been tested extensively on adult materials. For example, Klare (1952) tested the Flesch Reading Ease and Dale-Chall formulae against the 16 standardized passages of the Ojemann tests (1934) and the 48 passages of Gray and Leary tests (1935), all developed for adult readers.

Critics of the formulae also claimed that the criterion passages were arbitrary or out-of-date (Bruce et al. 1981, Duffy, 1985). The developers responded by working with new criterion passages as these became available and the new Dale-Chall formula (1995) as well as the Flesch-Kincaid formula were validated against normed passages from technical manuals (DuBay, 2004:44). New readability formulae were developed, notably those of Bormuth (1966) and Fry (1968), providing formula developers with a host of new criterion passages. The Fry Readability Graph, a well-used readability test that uses a graph is briefly outlined below.

2.1.3.1. THE FRY READABILITY GRAPH AS A READABILITY MEASUREMENT

Edward Fry created a readability test that uses a graph (Fry, 1963, 1968). His original graph determines readability through high school and was extensively validated with comprehension scores of primary and secondary schools and by correlations with other formulae (DuBay, 2004:44). In 1977 he extended his graph to measure college readability levels. He again makes use of the two strongest predictors of readability as his graph uses number of syllables and average sentence lengths in 100-word samples.

Readability researchers have long taken pains to recommend that because of their limitations, formulae are best used in conjunction with other methods of grading and writing texts. Ojemann as early as 1934, warned that the formulae were not to be applied mechanically, a caution expressed throughout readability literature.

George Klare and colleagues (1985) stated that for these reasons, formulae scores are better thought of as 'rough guides' rather than highly accurate values. However, scores derived from readability formulae provide quick, easy help in the analysis and placement of educational material. Readability researchers such as Flesch (1948,1974), Klare and Buck (1954), Klare (1980), Gunning (1952), Dale (1967), Gilliland (1972) and Fry (1988) wrote extensively on the rhetorical factors that require attention such as organization, content, coherence and design.

2.1.4. SUPPORT FOR THE USE OF READABILITY FORMULA WHEN ASSESSING THE READABILITY OF TEXTBOOKS - CURRENT READABILITY RESEARCH USING CLASSICAL FORMULAE

Readability formulae have the strength of objectivity and consistency and in addition there is a very large data base dealing with the validation of readability formulae (Fry, 2002).

2.1.4.1. CORRELATION BETWEEN CLASSICAL READABILITY FORMULAE AND CLOZE TESTS

A study was conducted by Gottfried Merzyn (Merzyn, 1987) into the readability of physics textbooks in senior secondary schools in Germany. His team applied three different methods to the same selection of four texts: they firstly gave the text sections to 20 physics teachers to critically assess, secondly they determined the readability of the texts according to readability formula developed for the German language and finally, they prepared cloze tests and administered them to the ninth graders using the texts. The texts were then ranked and the results compared. All three methods led to practically the same rank order of difficulty and they reported that although the readability formula and the cloze tests regard only a few of the features of text, they nevertheless give a satisfactory indication of the difficulty of text extracts. Merzyn also argued for the need to “bring the textbooks and instruction of science down from the frustration level to a level of easily understandable language” (1987:488).

2.1.4.1.1. CORRELATION BETWEEN QUANTITATIVE AND QUALITATIVE READABILITY MEASURES

A study conducted by Jeanne Chall and Sue Conard in 1991 (Chall & Conard, 1991) in which they questioned whether textbooks should challenge students and then assessed a number of physical science textbooks, confirmed research of the past 70 years on the essential validity of the quantitative measures of reading ability and text difficulty. They found considerable similarity between quantitative and qualitative measures of text difficulty. Students cloze-test comprehension scores, their judgments of passage difficulty (whether ‘easy’, ‘just right’ or ‘hard’) and the readability scores of the passages were all positively associated. Qualitative estimates of reading stages and question difficulty were positively correlated with quantitative readability scores. They recommended that quantitative measures of student ability as well as text difficulty not be abandoned for qualitative ones. Applying both qualitative and quantitative measures provides the strongest case for readability levels of texts.

The literature reviewed thus far has focused on the readability of texts written for English first language speakers. The review continues with a consideration of the classical readability formulae and their validity for English Second Language (ESL) texts.

2.1.5. READABILITY FORMULAE AND THEIR USE IN ENGLISH SECOND LANGUAGE ASSESSMENTS

ESL teachers use English readability formulae to match texts to their students' reading levels. However, the validity of the formulae for ESL use has gone largely untested. Two studies addressed this issue, with divergent results. Brown (1998) found that classic formulae were not very accurate predictors of English Foreign Language (EFL) difficulty, while Miyazaki (Miyazaki in Greenfield (2003)) found that they predicted for EFL about as well as they did for native English readers. Both studies developed accurate ESL/EFL readability formulae that could be used to determine the readability levels for ESL/EFL students. These formulae were intricate and not easy to apply. Greenfield (2004) analyzed both studies in depth and attributed the difference in their findings to Brown's choice of random passage sets. When Brown's formula for EFL/ESL was applied to the passages used in the Miyazaki study, the results correlated with those of Miyazaki, agreeing with observed ESL/EFL difficulty and predictions by classic formulae. This supports the finding that the classic formulae are valid for ESL/EFL used.

In the following section, Section 2.2 of this literature survey, issues relating to the cognitive-structural aspects of text are reviewed. The overview of this aspect of readability does not attempt to be all-inclusive but instead focuses specifically on aspects that relate to the readability of expository text and particularly, scientific expository text in a senior secondary school context.

2.2. THE COGNITIVE – STRUCTURAL READABILITY PARADIGM

The cognitive theorists and linguists, beginning in the 1970s, argued that reading was largely an act of thinking and that meaning is constructed by the reader as he or she makes inferences and interpretations. The role of the long-term and working memory in the reading process was considered, and the cognitive act of linking new knowledge about the topic in the text to the prior knowledge of the reader, was studied.

Pertinent cognitive-structural aspects that affect the readability of texts are now reviewed.

2.2.1. THE ROLE PLAYED BY THE RHETORICAL STRUCTURES / SCHEMA OF EXPOSITORY TEXT AND THEIR EFFECT ON READABILITY

For any reader, text can only be processed and comprehended meaningfully once placed in an overall framework or schema (Anderson, Pichert & Shirey, 1983; Lorch & Puzles Lorch, 1985; Armbruster, 1986). The schema enables the reader to situate the major themes, secondary themes, and supporting details in relation to one another in such a way that comprehension and recall are facilitated. Two types of schemas are believed to play a role in the comprehension and recall of information from text: content and textual (Anderson, Pichert & Shirey, 1983). Content schemas embody the reader's existing knowledge about real and imaginary worlds whereas textual schemas contain knowledge about the conventions of organized discourse.

Readers comprehend a text when they are able to activate schemas that match the particular content and structure of the material. As they begin to read, readers search for schemas that elucidate the text, and using these, construct a partial and tentative model of the text's meaning. This model serves to scaffold the continued search through the text and is progressively refined as the reader gathers more information from the text (Armbruster, 1986). Comprehension is thus dependent on the progressive refinement of a coherent model of the text's meaning by the reader. According to schemata theory, therefore, meaning does not reside in the text alone, but is the product of the interaction of reader and text.

2.2.1.1. TEXTUAL SCHEMATA AND THE DESIGN OF CONTENT-AREA TEXTBOOKS

Research has identified a number of textual schemas that need to be accessed by the reader. For the purpose of this study, however, the discussion will focus on higher order textual schemas at the level of extended discourse. Armbruster (1986) notes that two types of textual schema operate at this level: those for the rhetorical structures found across a wide variety of texts and those specific to a type of content. Armbruster further notes that the more general schemas found across a wide variety of texts appear to capture the fundamental patterns of human thought. The most common of these, reflected in a few basic text structures are: listing, comparison/contrast, problem/solution, cause/effect and temporal sequence. Many researchers have found these to be basic to improved comprehension and recall among both first and second language speakers (Meyer, Brandt & Bluth, 1980; Foo, 1989; Goh, 1990; Carrell, 1984). Research has also shown that readers who have knowledge of textual schemata are able to comprehend main ideas with more ease, recall more specific information (Meyer et al., 1980; Meyer & Rice, 1984) and are better able to distinguish between important and unimportant information (Dole et.al.,1991). It has also been shown to help in the recall of topics that are unfamiliar to the reader (Taylor & Beach, 1984; Alvermann & Qian, 1994).

Although research suggests that the ability of the reader to discern and use text structure plays a major role in the success of comprehension, the author also plays an important role. The author determines how explicit the text structure is and how well it is structured. Content subject textbooks have been criticized as being 'inconsiderate' of the apprentice reader in not making rhetorical structures clear (Armbruster, 1984, 1986 ; Carrell, 1984 ; Sharp, 1999). As noted above, textbooks are not read in isolation and the reader's context in terms of reading ability and cognitive development should be considered constantly by the author of the book. Research has shown that 'considerate' rhetorical structuring facilitates the comprehension of text for the first and to an even greater degree, the second language learner.

Considerate rhetorical structuring includes clear signalling devices, titles, subtitles and the making of logical relationships explicit. Alastair Sharp (1999) conducted a survey among Chinese schools (secondary/high school level) in Hong Kong and produced a paper in which he discusses the use of English medium textbooks in bilingual situations. He argues that language and textual constraints both seem to inhibit the efficient reading of content subject textbooks in school. He emphasizes that although correctly selected vocabulary is vital in reading comprehension and recall, the way the text is structured also plays a role. He contends that this issue is given too little emphasis in the preparation of school textbooks by authors and publishers. He recommends and offers examples of improved writing (see Appendix D). His improvements offer clearer signalling devices, titles, subtitles, introductions, topic sentences and logical relationships are made more explicit. Bold numbering and additional elaboration are two further points that he notes help to make text more 'considerate' of the reader. In this connection Langhan cites Williams (Langhan 1990:91) when he emphasizes the importance, particularly in the beginning of a chapter, of giving the reader a summary/overview of the chapter, contents, their sequence and interrelationship.

The use of unprincipled paragraphing is another practice which tends to make texts 'inconsiderate' of the reader and especially the ESL reader and so impairs readability. Langhan (1990:89) writes of this 'unprincipled paragraphing' and notes the young ESL reader's need for supportive text which provides clear, well organized paragraphs, ideas logically connected and propositions following on logically one from another. He cites Williams (1985) who pointed out that readability is greatly improved if the topic sentence is placed as early in the paragraph as possible. Conversely, if the topic sentence is nowhere near the beginning, the readability is greatly reduced.

Lanham emphasizes the danger of titles and headings being misleading (Langhan 1990:90) and so posing a serious readability problem for young ESL readers. He states that in light of the importance of a reader's activated background knowledge for the construction of meaning during reading and given the likely linguistic and cultural limitations on the young ESL reader's accessible background knowledge, it is crucial that headings should be both meaningful and predictive (Williams, 1985:56; Lanham 1986:9, 1990:4). He stresses that

headings should be as specific as possible, thus enabling the reader to predict the contents of the section concerned.

In addition, Steinley (1987:117) notes that the reader can only make use of headings if the paragraphs under them are properly organized, and Meyer (1989:9) stresses again, the advantage to readability of topic sentences being placed at the beginning of a paragraph.

In her discussion of the 'Role of the Author' in writing texts for scholars, Armbruster (1986) recognizes the responsibility of the author in producing well structured texts. She specifically refers to the 'clues' (as discussed above) that the authors use for text structures and recommends that these be explicit.

2.2.1.2. THE INFLUENCE OF RHETORICAL STRUCTURES ON PRIOR KNOWLEDGE ACTIVATION

Afflerbach (1990) investigated the influence of prior knowledge on the main idea construction strategies of expert readers when reading text where the main idea was implicit. Using readers from the field of chemistry, and texts that were both familiar and unfamiliar to the readers, he identified three methods or strategies that readers use for constructing main ideas in implicit text: automatic construction, the draft-and-revision strategy, and the topic/comment strategy.

He concluded that readers' prior knowledge influenced the efficiency of a range of complex processes necessary for main idea construction, noting that these processes were performed more automatically (or efficiently) for text that was in a familiar content domain, freeing up cognitive resources for the main idea construction task. However, when these comprehension processes were not automatic, working memory resources were compromised (Baddeley & Hitch, 1974; Britton, Glynn & Smith, 1985).

His study offered several possible implications for education practice, among them that it is important to acknowledge the challenging nature of the main idea construction task. In addition, the results of the study demonstrated that if the reader's prior knowledge for the text topic was insufficient, the difficulty of main idea construction is compounded.

2.2.2. THE CONTRIBUTION OF PRIOR KNOWLEDGE AND TEXT COHERENCE TO COMPREHENSION

McKeown, Beck, Sinatra and Loxterman (1992) conducted an interesting investigation into the contribution of prior knowledge and coherent text to comprehension. They upgraded a group of students' background knowledge on a section of school history and then divided the group into two subgroups. To the one they gave an incoherent text and to the second, a coherent text. Testing comprehension they found that the students who read the revised text were able to utilize the knowledge gained from the background knowledge instructional module to focus on and remember the most important information from the text. This was particularly evident from the examination of responses to questions. The revised group was more successful in responding to key questions that indicated some grasp of the core principles discussed in the text. The students who had read the original text, although they received the same background information, were less able to exploit the advantage provided by that information. It seems that the nature of the original text prevented students from bringing their knowledge to bear in constructing meaning from the text.

A finding that adds an extra dimension to the study, was that of the revised groups' poor performance on certain specific content. This finding gives support to the currently explored phenomenon that background knowledge overrides text information in such a way that readers recall text or respond to questions with information from their knowledge base, even though it is not supported by, and in some cases is even contradictory to, the text (Alvermann, Smith, & Readence, 1985; DiSessa, 1983; Marshall, 1989; Schoenfeld, 1985).

The performance of the two groups in the above study reveal that the original textbook passages, coupled with fairly extensive teacher intervention to provide background knowledge, yielded comprehension that was below that of students who received the preparation component and the revised text. This result counters another argument sometimes put forth in the debate on textbooks: that is, efforts to make textbooks more coherent are unnecessary because the teacher fills in information which will make up for

any gaps in the text material. As McKeown et al's research reported, extensive preparation to provide background knowledge did not compensate for the inadequacies of the text; there was still a substantial advantage for the revised text.

The study sheds some additional light on the contribution to text comprehension of two important components of that process, background knowledge and text coherence. As Roller (1990) points out, text structure and background knowledge interact in their effect on comprehension. Knowledge of varying degrees can compensate for varying levels of structure or coherence. Similarly, greater coherence can compensate for some knowledge gaps. However neither background knowledge, nor text coherence, can completely compensate for the inadequacies of each other.

2.2.3. THE 'SEDUCTIVE DETAILS' EFFECT ON THE READABILITY OF EXPOSITORY TEXTS

Textbooks remain a necessary and powerful support in the classroom, second only to the lesson as the instructional medium of choice for presenting information to students. However, students often find the material boring (Harp & Mayer, 1998) and textbook writers, in an attempt to avoid this, resort to adding *seductive details* for increasing students' interest in a text. These *seductive details* are highly interesting and entertaining pieces of information that are only tangentially related to the topic and may be irrelevant to the author's intended theme (Garner, Brown, Sander, & Menke, 1992).

Extensive research has been done examining the use of *seductive details* by authors, and research findings show that adding seductive details (in the form of sentences) to a passage actually reduces students' retention of the main ideas in a passage (Garner, Alexander, Gillingham, Kulikowich, & Brown, 1991; Harp & Mayer, 1997; Hidi & Baird, 1986; Wade, 1992). This effect has been termed the seductive details effect. Also consistent with the seductive details hypothesis, is that readers typically remember interesting adjuncts included in a passage rather than structurally important ideas (Garner et al., 1992; Hidi & Anderson, 1992).

In attempting to discover just how seductive details interfere with comprehension, Harp and Mayer (1998) conducted a comprehensive study investigating this issue of readability.

They considered the three processes that an active learner must use to construct a coherent mental representation of information contained in text and illustrations: *selecting, organizing, and integrating* (Mayer, Steinhoff, Bower & Mars, 1995). Selecting, involves paying attention to the relevant pieces of information in the text; organizing, involves building internal connections among the selected pieces of information, such as noting that one step is the cause of the next step in a cause-and-effect chain; and finally integrating, involves building external connections between the incoming information and prior knowledge existing in the learner's long-term memory. They hypothesised that seductive details could interfere with any one of these three processes. Harp and Meyer labelled these: the distraction hypothesis (seductive details interfere with the selection and retention of relevant pieces of information), the disruption hypothesis (seductive details interfere with the building of internal connections among selected pieces) and the diversion hypothesis (seductive details interfere with building connections between incoming information and existing prior knowledge).

Harp and Meyer's results showed conclusively that seductive details interfere with the integration process whereby incoming information is connected with existing prior knowledge. In summation they added:

Taken together with Garner et al.'s (1991) findings, the results we obtained in this study suggest that avoiding or preventing the activation of erroneous prior knowledge in the reader can reduce the seductive details effect. One way to discourage inappropriate schema activation is to delay the introduction of seductive information until after the reader has processed the important material. Another way is simply not to introduce seductive details at all.

(Harp & Mayer, 1998:18)

The results obtained in the above study provide support for a theory of cognitive interest. Cognitive interest, as opposed to emotional interest, results from the reader's satisfaction in understanding what he or she has read. Although their focus was on measures of cognitive understanding, Harp and Mayer, (1997) have measured emotional interest in previous studies. Both types of interest can be promoted by the content and structure of the text (Harp & Mayer, 1997). Cognitively interesting adjuncts, such as summaries, explanative illustrations, and text cohesiveness, have been shown to promote understanding (Harp & Mayer, 1997). On the other hand, emotionally interesting adjuncts, such as *seductive details*, appear to promote affective arousal in the reader (Kintsch, 1980).

Research on the *seductive details* effect suggests that this kind of emotional arousal does not lead to better understanding of textbook lessons (Garner et al., 1989; Garner et al., 1991; Harp & Mayer, 1997). In particular, the findings demonstrate that an important way to promote cognitive interest is to help students to activate a relevant internal knowledge structure, that is, to activate their appropriate prior knowledge. *Seductive details*, as evidenced from experiments and research, appear to give readers an inappropriate context for the reading and thereby raise false expectations about what they are reading. In their search for ways to construct meaning from the text, readers are drawn to *seductive details* as an organizing context.

2.2.4. THE USE OF GRAPHICACY IN SCIENCE TEXTS AND THE EFFECT OF THIS ON READABILITY

Richard Mayer (1989) investigated the use of illustrations in expository texts with the purpose of exploring their part in improving the comprehensibility of such texts. He had investigated the effects of advance organisers (Mayer 1975a, 1976, 1978, 1983; Mayer & Brotnage, 1980), signalling and adjunct questions. His work on the role played by illustrations was based on the idea that different instructional manipulations may have effects on different aspects of cognitive processing in different learners. He argued that assimilation theory – the idea that learning involves integrating new information with existing knowledge - suggested three primary functions of the cognitive process: guiding selective attention towards certain information in the texts, fostering the building of external connections between ideas from the text and finally building external connections between the text and the learner's existing knowledge (Mayer, 1982, 1984, 1985, 1987). He then turned his attention to the role of illustrations as 'potential vehicles' for aiding students' understanding of expository text.

He focused on explanatory expository text and drew his sample of students from a group that had little background knowledge of the mechanics text chosen. His results were consistent with the idea that illustrations can affect the cognitive processing of the reader and in particular, that the labelled illustrations used, helped the students guide selective attention and build internal connections. The results of his experiments also highlighted

that the effects of labelled illustrations depend both on the graphics and the labels. Providing only pictures (without corresponding labels) or only labels (without corresponding pictures) did not allow students to build useful mental models. Not surprisingly, providing labels that repeated explanative information from the text improved student recall of information.

Langhan (1990) also reviewed the role of pictures and diagrams in primary school texts. He cited Smith and van Rooyen (1990:87) who reported that visuals accompanying text have three main functions:

- They assist with the construction of meaning as the visual medium together with language is intended to provide meaning for the reader of an unfamiliar language.
- They reinforce the learning process by combining visuals and language and providing an environment for optimal learning.
- They provide constructive motivation in that visuals generally get attention and encourage the reader to delve deeper and to find out more.

2.2.5. WORKING MEMORY AND THE INFLUENCE OF WORKING MEMORY CAPACITY ON READABILITY

For the purposes of this research, it is necessary to briefly outline a definition of working memory, sum up its relationship to science achievement and discuss how to apply findings from working memory research to facilitate the development of science learning and teaching materials.

During cognitive activity, working memory (WM) is responsible for temporarily maintaining and manipulating information (Baddeley, 2002). It is linked to a wide range of high-level cognitive abilities such as reasoning, problem-solving, and learning (Kyllonen & Christal, 1990) and is also closely related to academic achievement in the domain of reading, writing, mathematics, and science (Gathercole, Pickering, Knight, & Stegmann, 2004).

2.2.5.1. THE DEFINITION OF WORKING MEMORY

Working memory is complex and this complexity has led to the development of a number of models used to measure and define it (Kyllonen, 2002). According to Miyake and Shah (1999), WM models have evolved from a single unitary memory store to a system containing multiple cognitive subsystems responsible for different storage and executive control functions. For example, Miller's (1956) finding that immediate memory stored only 7 ± 2 "chunks" of information represented the early understanding of WM as a single information store whereas Baddeley and Hitch's (1974) model of WM had evolved the single unitary model to that of a multiple-component system. Their system consisted of a phonological loop, a visio-spatial sketch pad, and a central executive thus beginning the era of decomposing WM into different components. Although researchers differ in their specifications of WM subsystems, most agree that WM includes multiple subsystems working together to activate task-related information, maintain activation, and manipulate information during the performance of cognitive tasks (Miyake & Shah, 1999).

2.2.5.2. WORKING MEMORY AND SCIENCE LEARNING

A number of studies have revealed that there is a positive correlation between working memory and science learning (Gathercole et al., 2004; Danili & Reid, 2004). As working memory capacity (WMC) limits the amount of information which can be concurrently processed, performance on science problem-solving tasks is expected to drop when the information load exceeds students' WMC (Johnstone & El-Banna, 1986; Opdenacker et al., 1990).

Researchers have taken two main approaches to deal with the limit of WMC to help students learn science and the one which has relevance to the readability of science texts is that of decreasing the information load in science learning materials. For the purposes of this study, decreasing cognitive load and studies around it are reviewed.

2.2.5.3. DECREASING COGNITIVE LOAD IN LTSM

Two factors contributing to the cognitive load are the presentation of materials (external cognitive load) and the complexity of learning materials provided to students (internal cognitive load). Thus, to decrease cognitive load, one could decrease external cognitive load by presenting the materials in a way that is easy to understand or by lessening internal cognitive load through reducing the interactivity among elements in the materials.

One of the strategies developed to reduce external cognitive load in learning materials, is to provide worked examples (Sweller et al., 1998) while another lies in the redesigning of learning materials that split students' attention, for instance from a text paragraph and a separate diagram to an integrated diagram (Sweller & Chandler, 1994; Danili & Reid, 2004). Measures to decrease external cognitive load also include using dialogue boxes, pictures, diagrams, and models to help students focus on the main messages and deepen their understanding through multiple coding channels.

Strategies to reduce internal cognitive load included presenting the materials in a more stepwise fashion, changing the presentation order of the materials, and relating learning materials to prior knowledge.

Johnstone and El-Banna (1986) conducted in-depth investigations into the areas of particular conceptual difficulty in chemistry in an attempt to find ways of reducing both internal and external cognitive load. The chemistry topics that they isolated as presenting particular difficulty to students were:

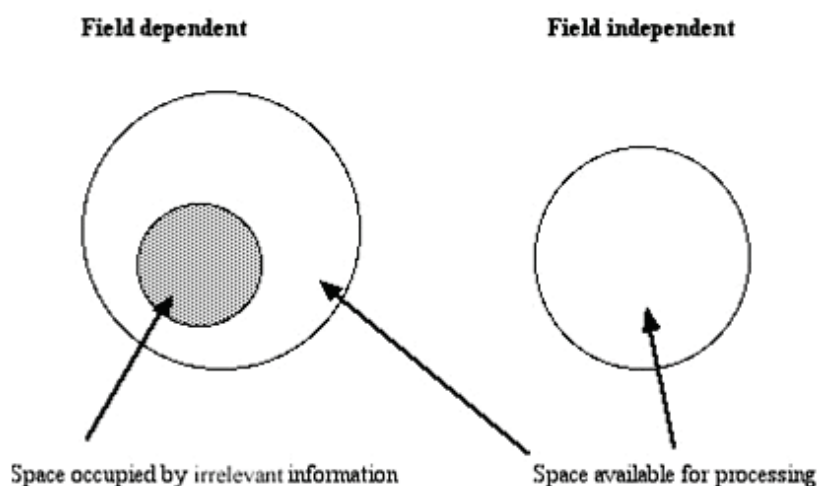
- Writing chemical formulae and equations
- Using chemical formulae and equations in calculations
- Volumetric work involving molarities
- Ion-electron equations
- Avogadro's Number and the mole
- Heats of reaction, Hess's Law and thermochemistry

- Redox reactions and E° values
- Equilibrium
- Organic formulae

The list of topics was then distributed among the research group and each topic was analysed for possible sources of difficulty and common factors among them. A common factor of 'information complexity' emerged and this led to investigations into the functioning of WMC as well as the influence of Field Dependence.

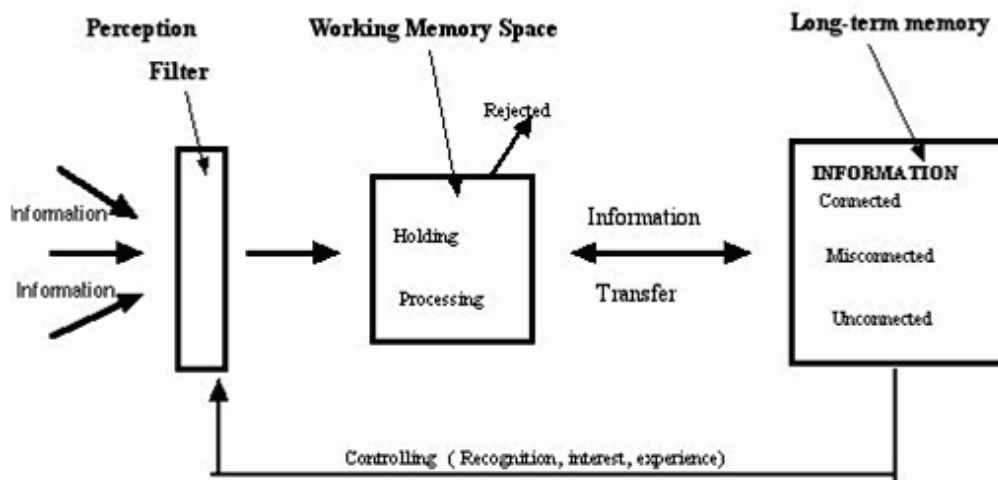
Field Dependent students - those easily distracted by irrelevant material - although having a high WMC, performed less well; in fact, they performed almost exactly as well as students who had a low WMC. The potential usable WMC (see Figure 3 below) was effectively reduced by the space taken up by the irrelevancies introduced by Field Dependence (Johnson 2006: 55).

Figure 3. Effect of Field Dependence upon available Working Memory Space



Adding then to the findings on WMC and Field Dependence, the team then adapted and shaped an Information Processing model as depicted below in Figure 4.

Figure 4. Information Processing Model



(Johnstone, 2010:2)

This model indicates that external stimuli, such as those presented in teaching and learning, are first perceived by the senses and filtered. The learner will attend to what is interesting, stimulating and familiar and to do this, the filter will be controlled by what is held in the Long Term Memory. Something cannot be interesting or familiar unless it is being compared with some previous knowledge. What is held in the Long Term Memory is crucial for this perception stage (Johnson, 2006:55). The information then admitted through the filter enters the conscious processing part of the mind, the Working Memory Space (or WMC). This space functions to hold the incoming information in temporary store and to operate upon the incoming information to make sense of it and prepare it for some response and / or to store it in the Long Term Memory.

The WM has a finite capacity and the consequence of this is that if:

- there is too much information to be held; or
- too much processing to be done 'on' the information; or
- in the case of language, there is translation to be done;

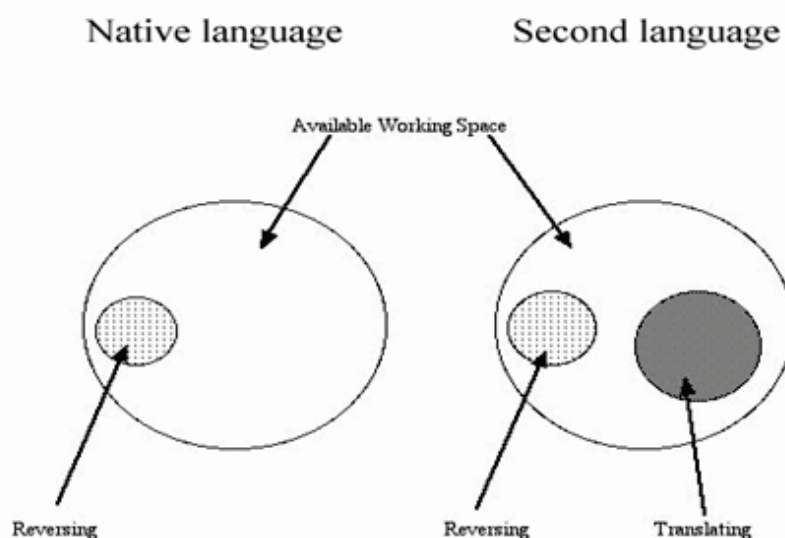
the WMC faces an overload and unsuccessful processing and storage takes place. A number of important research lines opened up as a consequence of, and informed by, the Information Processing Model, the two of interest for this study being the function of language in science teaching and learning and multi-level learning.

2.2.5.3.1. THE LANGUAGE OF LEARNING AND WORKING MEMORY SPACE

A language study was conducted mainly by Cassels (reported in Cassels & Johnstone, 1985) and, twenty years later, by Johnstone and Selepeng (Johnstone & Selepeng, 2001). Cassels reasoned that the language held in Long Term Memory would affect the filter and the WM processing, and he set out to find the vocabulary which might cause misunderstandings and had the potential for the construction of misconceptions or alternative frameworks. He eventually isolated more than 100 words, commonly used in school science, which caused trouble. These were words that teachers could easily assume that the pupils had a grasp of their scientific meaning. However, a word such as 'volatile' could be interpreted by pupils to mean 'unstable', 'explosive' or 'easily vaporised', based upon their common, everyday experience. All the meanings could make sense in a chemistry text, but two would have the potential for the construction of alternative frameworks. Another word is 'equilibrium' which carries with it a cluster of ideas from physics and from everyday experience, all of which contain the seeds of problems leading to alternative frameworks. 'Equilibrium' suggests balance and static state, an idea which is unhelpful in chemistry. Cassels and Johnstone (1985) also found that the problem was even greater for pupils whose first language was not English. This had important consequences for those teaching ethnic minority groups in western countries, but even more so for pupils in ex-colonial countries where English was used as the instructional medium for science teaching, despite the fact that the native language and culture was very different.

Johnstone and Selepeng (2001) followed this problem further and measured the effective WMC for pupils when the Digit Span and Digit Span Backwards Tests were applied in the native language and in the second language. The effective WMC was, on average, 1.6 units (20%) less in a second language than in the native language. In other words, pupils were handicapped in their science learning and reading by the reduction of their WMC in a second language. The processing of the second language was taking up some of the valuable processing space needed for the understanding of the science (see Figure 5 below).

Figure 5. Loss of Working Space when using a second language

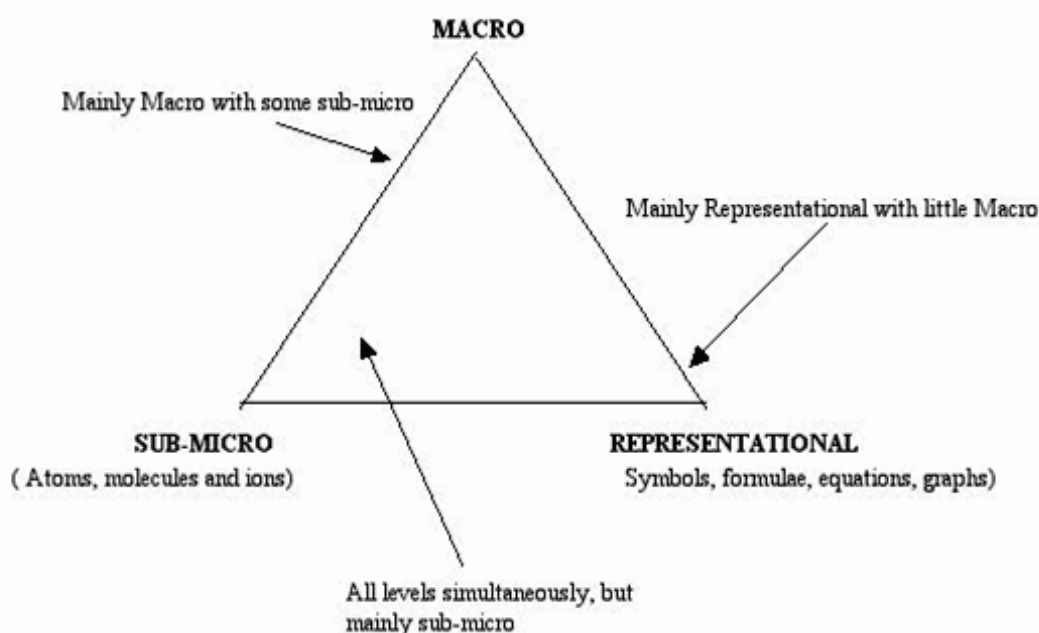


(Johnstone & Selepeng, 2001: 22)

2.2.5.3.2. FUNCTION OF MULTI-LEVEL LEARNING AND ITS ROLE IN RAISING READABILITY LEVEL

It has been recognised that WMC overload can occur at the early stages of learning chemistry because of the very nature of the subject (Johnstone, 1991). Pre-1960, the atomic and molecular aspects of chemistry were not as evident in the early stages of learning the subject as they are now. Atomic and molecular structure and the nature of bonding tended to be taught during the later years in school. However, we now have a situation where the particulate nature of matter (the atomic and molecular development of this) and the introduction of ions and bonding are found early on in introductory chemistry. Pupils are now confronted with the simultaneous introduction of unfamiliar substances in a lesson (macro level), combined with a description of them in molecular terms (sub-micro level) as well as a representation of them by symbols and formulae (representational level) (see Figure 6 below).

Figure 6. The three conceptual levels of chemistry



(Johnstone, 2010:3)

In many lessons or texts, there is a blend of all three experiences simultaneously, represented by a point within the triangle, its position being determined by the relative proportion of the three components. Inside the triangle lies the potential for gross overload of WMC.

The South African science curriculum takes cognisance of the problem described above as an excerpt from the NCS Physical Sciences Content Document reveals:

“A number of respected science educators have drawn attention to the difficulty for beginners in managing, all at the same time, the macro-level, the micro-level, and the symbolic-level descriptions of chemical phenomena. It is indeed inherently difficult to think and comprehend in three ways, all more or less at the same time. Many chemistry teachers compound the problem by using confusing language or simply by avoiding the issue”

(DoE, 2006:13)

Great care must be taken in the preparation of textbooks to compensate for the difficulty that the reader will have managing the macro-, micro- and symbolic levels all at once. This compensation takes the form of organizing the material in a step-wise fashion and ensuring that the clarity of the graphicacy gives maximum support to the concepts being developed in the text.

2.3. THE LANGUAGE OF SCIENCE AND THE CHALLENGE PRESENTED BY ITS COMPLEXITY

2.3.1. SCIENTIFIC VOCABULARY AND ITS ROLE IN RAISING READABILITY

Vocabulary is the aspect of reading that students readily identify as being the most difficult (Campbell, 1987:123) and indeed, according to Wellington and Osborne (2001:9), “many of the words in science are complete strangers to students and often, a student can answer questions in science without truly comprehending the words being used.”

Merzyn (1987) drew an interesting analogy when he reflected on the study of a school physics textbook in Germany by Brämer and Clemens (1980). They identified 2000 different technical terms used in the text-book for students in grade 7 to 10 and further noted that every page contained approximately five new terms. Meyer compared this with foreign language studies, where 2000 words represents the upper limit of vocabulary knowledge, for example, dictionaries for such students are written within a 2,000 word vocabulary. He noted that when learning a foreign language, students are introduced to between 2 and 6 new words a lesson, compared with the 8 new terms per physics lesson. Although Merzyn’s analogy could be considered extreme, it nonetheless emphasizes that the language of science can be compared to a foreign language and that care must be taken in the manner in which words are introduced and used. In concluding his review of the studies of the language of science textbooks in Germany, he commented that the level of frustration of the adolescent readers needed to be reduced and that language that could be easily understood should be used.

Wellington and Osborne (2001) classify science words according to their level of abstraction and divide them into four categories. When discussing the danger of students meeting words, especially concept words, too early in their school career, they relate their

taxonomy to the Piagetian stages of development. They remind teachers that a student needs to be at the formal-operational stage (11 – adult) before he or she can acquire any meaning for a term denoting a theoretical construct (Wellington and Osborne 2001:170).

In **Figure 1** below, is Wellington and Osborne’s taxonomy of scientific terms.

(Wellington and Osborne, 2001:20)

<p>Level 1: Naming Words</p> <p>1.1 Familiar objects, new names 1.2 New objects, new names 1.3 Names of chemical elements 1.4 Other nomenclature</p>
<p>Level 2: Process Words</p> <p>1.1 Ostensive Definition 1.2 No ostensive definition</p>
<p>Level 3: Concept words</p> <p>3.1 Sensory Concepts 3.2 Having dual meaning 3.3 Theoretical Concepts</p>
<p>Level 4: Mathematical ‘words’ and symbols</p>

Figure 1 Wellington and Osborne’s taxonomy of scientific words

The first category, ‘naming words’, are words that denote identifiable, observable, real objects or entities: words like ‘table-salt’ and ‘meniscus’. At a slightly higher level, some learning in science involves giving new names for unfamiliar objects: examples include the names of laboratory equipment like a Bunsen burner, pipette and conical flask.

The second category of scientific words, Wellington and Osborne called 'process words' and they divide these into those that have an ostensive definition i.e. can be seen; and then at a higher level, those without an ostensive definition. Process words denote processes that happen in science, some the teacher can demonstrate, like evaporation and others, like evolution, cannot be seen.

The third category of words in science is also the largest category. These are concept words: for example, words like 'work', 'pressure', 'temperature' and 'heat'. This is the area of science, proposed by Wellington and Osborne, where the most learning difficulties are encountered. Concept words denote ideas and are often part of a vertical network, i.e., the understandings of one word (such as 'power') depends on the prior understanding of other words (such as 'work' and 'energy') and without prior understandings, the structure collapses. They note that many words can start as a name but, through language development in science, are gradually used as a concept. For example, 'fuel' may be a name for petrol or paraffin, but gradually it acquires a general, conceptual meaning such as 'flammable material yielding energy'.

At the lowest level, some concepts are directly derived from experience and can be defined ostensively by pointing to examples where the concept is evident, for example: 'dissolve'. A demonstration in the laboratory can bring the word 'dissolve' to a concrete level as students watch the demonstration.

Other concepts have dual meanings and these cause great difficulty for students. For example, in physics, the concept of equilibrium has a completely different meaning to the concept of equilibrium in chemistry.

Finally concepts that belong to the third category, they call theoretical concepts. Words like: 'elements', 'atoms', 'mixture', 'electron', 'compound', 'valency' and 'mole' to name but a few. These cannot be seen or even demonstrated; they are totally abstract and referred to as unobservable entities.

The highest level of abstraction is that of mathematical words and symbols as well as chemical words and symbols. This level is reviewed in greater depth below in section 2.3.4.

Wellington and Osborne (2001) make the following recommendations with regard to reducing the vocabulary barrier in science writing:

- avoid long sentences
- keep to one idea or concept per sentence
- beware of technical terms which have not been introduced
- avoid, as far as is possible, what Barnes (1973) called ‘language of secondary education’, terms like ‘relationship with’, ‘becomes apparent’, ‘derived from’ etc.
- keep language brief and concise
- use graphs, diagrams and illustrations to break up text where possible
- use plenty of structures to guide readers such as headings that stand out, summary/key points

Williams (1989) adds that glossing can be useful, bearing in mind the following important readability factors:

- Glossaries sometimes contain too many abstract words that defy the formation of a mental image.
- A glossary need not always be given in words. Sometimes artwork and a few words are better.
- Examples in glossaries are almost always helpful.
- A glossary should not contain words that are more difficult than the word being glossed.

2.3.2. COMPREHENSION DIFFICULTIES ARISING FROM THE USE OF NON-TECHNICAL TERMINOLOGY IN SCIENCE TEXTS

In addition to the difficulties arising from the use of technical terms, non-technical words seem to pose a greater problem. Non-technical vocabulary refers to terms that have one or more meanings in everyday language but which have a precise and sometimes different

meaning in a scientific context (Ali & Ismail, 2006). The comprehension of these terms, poses an acute problem to students and in particular, to students who study science in a language that is not their own (Gardner, 1972; Cassels & Johnstone, 1985; Johnstone & Selepeng, 2001; Ali & Ismail, 2006).

Cassels and Johnstone (1985) conducted a landmark study in which they probed students' understanding of these non-technical words. They based their study on the work of Gardner (1972), who had, in an earlier Australian study, isolated 95 problematic words. They extended this study by testing each word in a number of contexts as they noted that the context of each word changed its intelligibility. An example of this is when they tested the word 'simultaneous'. The word scored very well if none of the other options offered contained the idea of "one event after another", but if this option did appear, even the senior pupils were divided between this and the correct option. The performance and the precision of meaning were inversely proportional: the more precise the meaning, the weaker the performance.

They concentrated on ninety-five words from the Gardner study and presented them as follows: questions were written for ninety of them in which the words appeared in four different formats; five words were kept in one of the four formats to act as a check on their sampling. The four formats were:

a) One word synonym without context

'Partial' can mean

- A. small
- B. whole
- C. large
- D. incomplete

b) The word appears in four everyday situations only one of which is correct

Which sentence uses the word converge correctly?

- A. The builder gave an estimate of the cost to converge the small bedroom into a bathroom.
- B. The officers discussed how the troops would converge on the town.

- C. The maths homework was to learn the theorem and its converge.
- D. As all of them were interested in fishing, the guests found it easy to converge on this subject over their meal.

c) The word appears in a science context stem.

The two chemicals seem to combine in a spontaneous reaction.

This means that the reaction

- A. was very quick.
- B. was explosive.
- C. once started increased vigorously.
- D. it happened by itself.

d) The word appears in a non-science context stem

The bird's song was audible. This means it was

- A. very beautiful
- B. a long way off
- C. able to be heard
- D. made while flying.

The test was sampled in 200 schools with 30 000 participating pupils from secondary schools (Grades 8 – 12).

Their findings were remarkable at the time and still are. Many of the words which teachers of science use at all levels are simply not readily accessible to their pupils. Pupils, when doubtful about the meaning of a word, are swayed by the context in which it appears and often take refuge in look-alike or sound-alike words. The pupils' understanding of some words (for example, 'tabulate') was described by Cassels and Johnstone as 'disastrous'. Understanding of a large number of the words (for example 'appropriate', 'estimate', 'standard' and 'essential') was deemed to be 'satisfactory'. However they reported that *very few* words were well understood.

Cassels and Johnstone's study was replicated in part in Britain by Pickersgill and Lock (1991), by Johnstone and Selepeng (2001), and in Malaysia by Ali and Ismail (2006). Each

one of these researchers, sought to further understand some aspect of non-technical word comprehension.

Pickersgill and Lock (1991) sought to understand the specific problems that non-technical words in science posed as well as the link between this understanding and a learner's verbal reasoning ability. They found that learners confused words which look and sound similar to the one being used and that they often take an opposite meaning to the one actually used. They also found a positive correlation between a student's score on verbal reasoning test and on a test of understanding of non-technical words in science.

Johnstone and Selepeng (2001) repeated, in small scale, part of the Cassels and Johnstone's work. They sought to determine if things had changed in the twenty year interim between the studies, as well as to compare the understanding of non-technical words of ESL and English first language learners. Their results revealed that the same problems indicated by Cassels' original work (Cassels, 1985) still existed but that the situation with second language learners has become even more serious.

Johnstone and Selepeng recommend that teachers with any class take care to check that "obvious" words are supported but that in classes with an ethnic mix, this procedure be even more carefully applied. They discourage rote learning of teacher language, recommending that pupils be encouraged to give explanations of concepts in their own words. They note that countries which teach science in a non-native language should be aware of the balance which has to be struck between overcoming problems about textbooks and the poor quality of learning in science experienced by learners whose mental working space is so drastically reduced by operating in an unfamiliar language.

Ali and Ismail (2006) undertook a similar study in 2006 in Malaysia where they tested the comprehension of non-technical words by Chinese students learning science in English. Their findings supported those of Johnstone and Selepeng and they further recommend that some time be given to teaching English in an academic context, thus aiding students to upgrade their level of comprehension of non-technical vocabulary

2.3.3. THE ROLE OF LOGICAL CONNECTIVES AND THE LANGUAGE OF INFERENCE IN RAISING READABILITY

Abstract ideas are logically developed and linked with one another in a number of ways, one of these ways being the use of logical connectives. Gardner (1980) defined logical connectives as being terms that indicate the nature of the relationship between the parts of a text and he added that they also function as transition words which contribute to the smooth flow of thought in written discourse.

Gardner (1980), in addition to researching the non-technical vocabulary of science (reviewed above in Section 2.3.2), also examined learners' comprehension of logical connectives. His 1977 study carried out in Australian schools using a sample of 16 000 students in the first four years of secondary school, found no fewer than seventy-five logical connectives that posed difficulty. The box in Figure 2 below, lists some of these.

Difficult Words	Very Difficult Words	Extremely Difficult Words
consequently	as to	conversely
hence	Essentially	moreover
i.e.	in practice	
nevertheless	Respectively	
on the basis of	Further	

Figure 2: A classification of the difficulty of a sample of logical connectives (Wellington & Osborne, 2001:16)

Many of the words in Gardner's list involve the language of inference; other connectives involve contrasts and comparisons; while still others connect causes and effects. Finally, logical connectives are also used in stating hypotheses.

Wellington and Osborne (2001) caution that although all these above mentioned functions are vitally important aspects of science and science education, teachers and writers of textbooks should be aware of the difficulty that connectives pose to learners and take special care in scaffolding them.

2.3.4. THE SYMBOLIC LANGUAGE OF SCIENCE AND THE CHALLENGE IT POSES FOR THE READER

An important contributor to the abstract nature of chemistry is the symbolic language it uses and according to Wellington and Osborne, (2001) (reviewed above in section 2.3.1), mathematical words (or symbolic language) represent the highest level of abstraction. In Chemistry, use is made of three types of symbolic notations (Jordaan, 1984) namely:

- Letter symbols such as those used to represent the elements, for example Na, N, O, Fe. Letter symbols are also used to indicate units of measurement, such as K for kelvin and Pa for pascal. Furthermore, symbols are used to represent physical quantities. Examples in this category are T for absolute temperature, p for pressure, and H for enthalpy. Symbols in which a combination of letters are used are also fairly common, such as the symbol for the chemical equilibrium constant K_c or K_p , K_{sp} (solubility product), and m_e (electron rest mass).
- Icons or iconic symbols such as [] (as in [HCl] to represent the concentration of HCl in mol/ dm³), \rightarrow , $<$, $>$, $+$.
- A combination of the first two types; that is, letter and iconic symbols combined. Examples in this category are Na^+ , ΔH , $^{\circ}\text{C}$, SO_3 , mol. dm³.

Marais and Jordaan (2000) analysed a typical exam question on chemical equilibrium and their analysis is explained in detail below. It serves to strengthen Wellington and Osborne's (2001) placing of symbolic language in the highest category of scientific words.

The question analysed was one on chemical equilibrium:

“Ammonia is prepared using the Haber process, which is based on the reaction of hydrogen and nitrogen according to the following equilibrium reaction:



How will the equilibrium be affected if

- (i) the temperature is increased;
- (ii) the pressure is increased?”

(Marais & Jordaan, 2000:1355)

Their analysis of the symbolism used in the above question indicates that a student has to go through a large number of cognitive steps before being able to answer the questions.

“He or she must:

- Identify the elements (nitrogen and hydrogen) and the compound (ammonia) from the given symbols (formulae).
- Interpret NH_3 not as a combination of N and H_3 , but as representing the ratio in which nitrogen atoms and hydrogen atoms combine to form ammonia.
- Understand that the coefficients mean that one molecule of nitrogen reacts with three molecules of hydrogen to form two molecules of ammonia.
- Understand that 1 mole (or volume) of nitrogen reacts with 3 moles (or volumes) of hydrogen to form 2 moles (or volumes) of ammonia.
- Interpret the “+” in the equation as meaning “reacts with” and not “added to”, as in mathematics.
- Interpret an arrow (\rightarrow) as meaning “forms” or “yields”.
- Interpret the double arrow (\rightleftharpoons) as meaning that the reaction is reversible; that is, that two reactions (a forward reaction and a reverse reaction) take place simultaneously.

- Realize that the reactants and products of this reaction are all in the gaseous phase; that is, that it is a homogeneous equilibrium system.
- Realize that the longer arrow to the left indicates that at equilibrium there will be more reactants than products, which suggests a small value for K_c .
- Not see the arrows of unequal length as meaning that the rate of the reverse reaction exceeds the rate of the forward reaction; that is, the arrows do not have to be of equal length to represent equilibrium.
- Know that H refers to the change in the heat of the reaction, or enthalpy.
- Interpret the meaning of $\Delta H < 0$ as meaning a decrease in the enthalpy of the system.
- Know that $\Delta H < 0$ refers to the forward reaction and that the reverse reaction is therefore endothermic. “

(Marais & Jordaan, 2000:1355)

It is evident that the density of symbolic language significantly raises the reading level of any chemistry texts and caution must be taken in both writing for and teaching chemistry to support the learner in this aspect of the scientific language. In the light of the review of research on working memory overload and multi-level learning (see section 2.2.5.3.), this caution is re-emphasised.

2.3.5. OTHER ASPECTS OF VOCABULARY AFFECTING THE READABILITY OF ESL TEXTBOOKS

David Langan, (1990), in a South African study of Geography textbooks being used in ‘black’ primary schools, reviewed the literature regarding vocabulary in content area textbooks. He identified twelve aspects of vocabulary, most often cited as affecting the readability of ESL textbooks and those that are relevant to this particular study are noted:

- Words of high frequency or familiarity to the reader will contribute to more readable writing. For example: ‘give’ instead of ‘assign’. Conversely, Lanham (1990:176) believes that unknown vocabulary, unsupported by context, is a major cause of

reading difficulty. In particular, ESL readers can be expected to have difficulty with text in which unknown words are too dense. These difficulties are compounded when the text does not provide semantic reinforcement in the form of known vocabulary.

- Concrete words are more readable than abstract words. For the ESL reader, one abstract word by itself, although less readable, is not likely to pose a major problem. But in association with other contributions to impaired readability like long sentences, complex syntax and paragraph structure; one abstract word might be the decisive factor for comprehension. “Abstract words are a particular problem for the L2 reader when presented in quick succession” (Williams 1985, in Langhan 1990).
- Shorter words are more readable than their longer synonyms.
- Intensifiers should be used appropriately. Writers need to be careful that intensifiers used are necessary and appropriate in meaning. Examples are emphasizees (e.g. definitely), amplifiers (e.g. completely) and downtoners (e.g. partly).
- Idiomatic expressions cause problems.
- Use specialist terminology only when necessary. Williams in Langhan (1990) writes that specialist terminology makes for economic writing with precise meaning, but that writers should be sensitive to terms that may not be familiar to the reader, and assist the reader to their meaning in cases of doubt.

Langhan (1990:53) cited Williams (1985) and Lanham (1990) and their suggestions as to how authors could introduce new or unknown vocabulary in order to facilitate the reading process. For the purpose of this study, the following need to be mentioned:

- Capitalize on the reader’s knowledge of the world and use their background knowledge
- Use comprehensible illustrations with labels
- Restate in more comprehensible terms

2.3.6. NOMINALIZATION AND TRANSITIVITY AND THEIR EFFECTS ON THE READABILITY OF SCIENTIFIC DISCOURSE

The representation of science as a series of events, classifications and definitions, couched in an impersonal context, further raises the readability level of science texts (Moss, 2000; Halliday, 2004). Moss argues that science as a human activity is absent in texts. She conducted an in-depth analysis of the 'readability' of two natural science texts written for grade 8 (ages 12-14) students and found aspects which she considered inhibitory to comprehension of the texts.

She notes that certain characteristics of the discourse of school science textbooks have been shown to present a vision of science as a set of unassailable facts, isolated from the everyday world and inaccessible to the common run of human beings (Moss, 2000). These characteristics include:

- the presentation of science as a product and not a process, as a set of finished and fixed data
- the omission of the human being as both subject and object of scientific enquiry
- Science being presented as 'absolute' and 'unquestionable' with little or no allowance made for uncertainty

She argues that science is thus placed at a distance from the world of the learner and comments that the presentation as science as absolute, *fait accompli*, is another feature of scientific discourse that distances it from the reader.

She notes that this presentation of science as a product and not a process is embodied in the tendency of scientific discourse to have a high density of grammatical metaphor (Halliday, 1994). Gill Francis (in press) states that nominalization is a form of linguistic expression which tends to objectify and make static phenomena which in the real world are dynamic and changing. While it may be argued that this discourse feature is a normal feature of scientific discourse, the result is also that students struggle to interact with clinical scientific facts and data sets.

Moss concludes that school education is 'science education' and not 'science' as such and notes that presenting learners with the type of impersonal language found in the texts is "like throwing them in the deep end of the swimming pool to sink or swim as best they may" (Moss, 2000:53) She recommends that texts limit nominalization and attempt a more 'human' approach in the presentation of materials.

2.4. LITERACY AND THE SOUTH AFRICAN GRADE 10 CLASSROOM

The textbooks being reviewed in this study have been prepared for the grade 10 South African classroom and as readability is influenced by the reading level of the students, it is necessary to gain some insight into this.

The entrance requirements at grade 10 level are gazetted as follows:

A learner will be promoted to Grade 10 only if s/he has satisfied the following achievement requirements:

- a) At least a **"moderate achievement"** or level 3 rating in **one of the Official Languages** offered and Mathematics;
- b) At least an **"elementary achievement"** or level 2 rating in **the other Official Language**; and
- c) At least a "moderate achievement" or level 3 rating in four other Learning Areas

(Extract of GOVERNMENT GAZETTE No. 29626, 12 FEBRUARY 2007)

The learners necessarily, would have achieved at least 40% (deemed a 'moderate achievement') in their home language; these being predominantly isiZulu at 23.8 percent of South Africa's population, followed by isiXhosa at 17.6 percent, Afrikaans at 13.3 percent, Sepedi at 9.4 percent, and English and Setswana each at 8.2 percent. The promotional requirement for the second language, the language of learning and teaching (LOLT) of the majority of the learners entering grade 10, is significantly lower, with only an "elementary achievement" of 30% required.

The results of a number of recent assessments of literacy in the lower grades, together with the drop-out rate between grades 10 and 12, would suggest that the pupils are ill-prepared to manage the subject content load expected of them in grade 10, in a language in which they have only shown an "elementary achievement".

A brief review of recent evaluations, both national and international is now presented as this gives valuable insight into learners' literacy level in English and Mathematics, the two areas that are relevant when attempting to understand the readability of science textbooks in the context of the South African grade 10 classroom.

2.4.1. NATIONAL SYSTEMIC EVALUATIONS

The *Assessment Policy for General Education and Training* (DoE, 1998) makes provision for systemic evaluations to be conducted at the Grades 3, 6 and 9 levels 'on a nationally representative sample in order to evaluate all aspects of the school system and learning programmes' (DoE, 2002:2).

In October of 2010, the Western Cape Education Department undertook systemic testing of all the grade 9 learners in the province. However these results will only be available in 2011.

The table below gives a breakdown of the country-wide 2004 testing of the grade 6 learners.

GRADE 6: 2004	Percentage
Language	38
Mathematics	27
Natural Sciences	41

Table 1: 2004 National Systemic Testing of Grade 6s

Source: Department of Education, 2003c and 2005d.

The learners' performance in 2001 and 2004 was poor enough, but the Literacy and Numeracy results in 2007 were worse, with highs of 48% and 49% in the Western Cape Province and lows of 29% and 24% in the province of Limpopo.

2.4.2. INTERNATIONAL EVALUATIONS OF SOUTH AFRICAN LEARNERS' LITERACY

Four international learning achievement assessments indicate that South African children perform exceptionally poorly compared to other participating countries. These studies include the Monitoring Learning Achievement (MLA) project, Trends in International Mathematics and Science Study (TIMSS), the Progress in International Reading Literacy Study (PIRLS) and the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ).

2.4.2.1. MONITORING LEARNING ACHIEVEMENT PROJECT (MLA) 1999

Results from the MLA project ranked South Africa the lowest out of 12 participating African countries for numeracy, fifth lowest for literacy and third lowest for life skills.

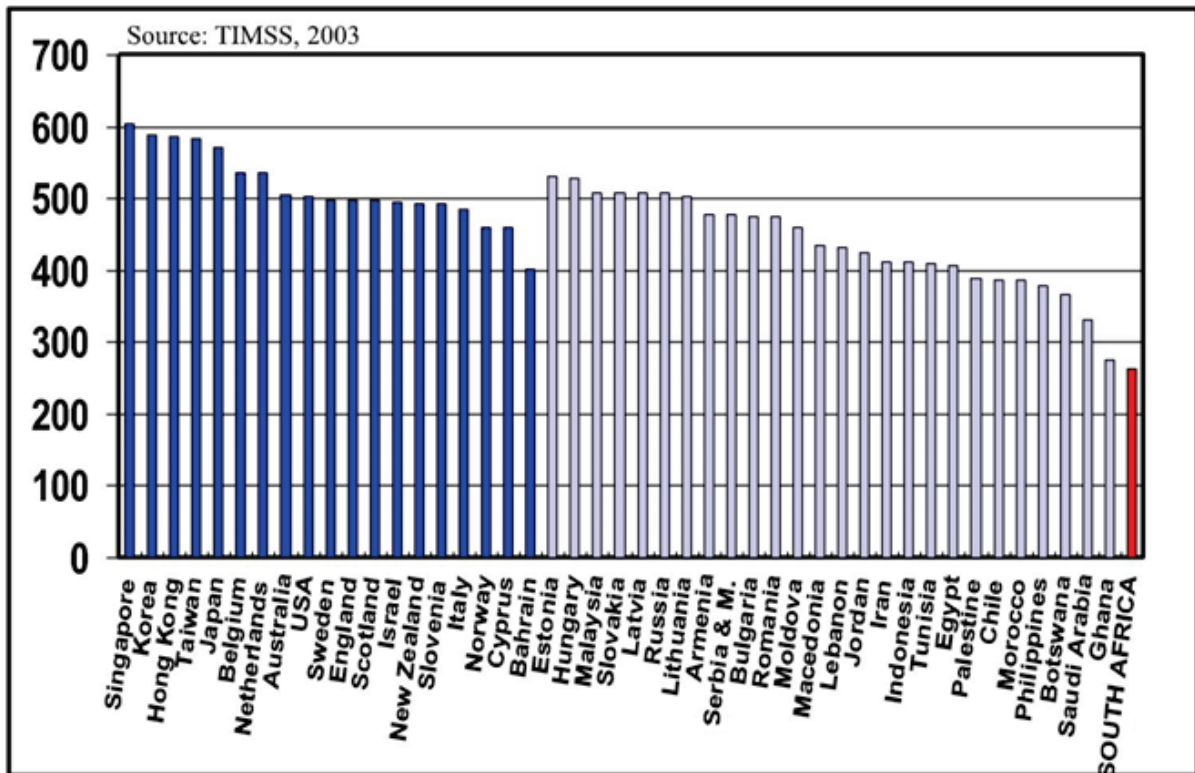
2.4.2.2. TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE (TIMSS)

South Africa participated in the TIMSS studies in 1995, 1999 and 2003. The studies measured grade 8 learning achievements in mathematics and science in several countries over this period. South Africa's performance in both the 1999 and the 2003 studies were disappointing, with lower average scores in both mathematics and science than all other participating countries (including African countries such as Morocco, Tunisia and Botswana).

The TIMSS results were reported in terms of mathematics and science average achievement scores. The scale average over the countries was set at 500 with a standard deviation of 100.

South Africa recorded the lowest performance in both mathematics and science of all the TIMSS participants. The international mathematics average scale score was 467 (SE=0.5) and the South African score was 264 (SE=5.5) while in science the international average

scale score was 474 and the South African score was 244. (see Graph 1, below)



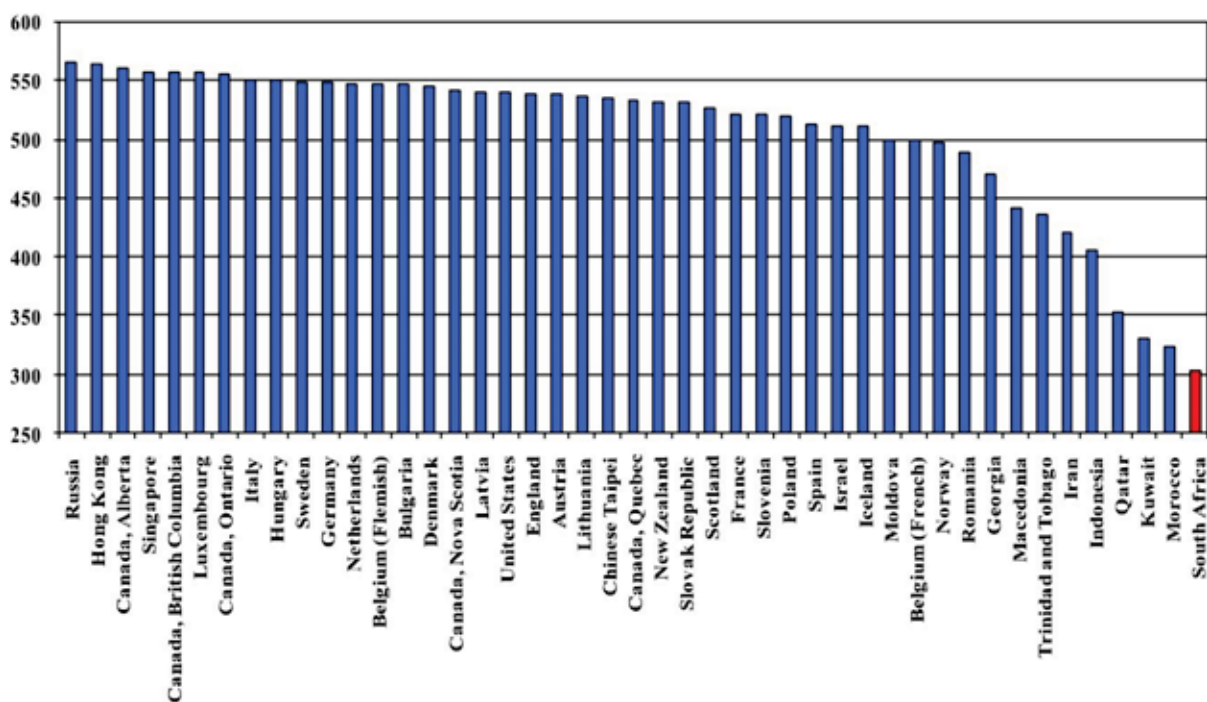
Graph 1: International Ranking of Achievement in the TIMSS study, 2003.

2.4.2.3. THE PROGRESS IN READING LITERACY STUDY (PIRLS)

PIRLS is an international test in literacy achievement undertaken by the PIRLS Study Centre at Boston College, Massachusetts, on behalf of the International Association for the Evaluation of Educational Achievement (IEA). The IEA’s studies of student achievement in school studies are intended to guide educational policies and practices around the world.

The 2006 PIRLS was the first PIRLS study in which South Africa participated. The assessment was carried out on Grades 4 and 5 learners (although the assessment was aimed at a Grade 4 level), in more than 400 schools, and in all 11 official languages. Learners were assessed in the language of learning they had used in Grades 1 to 3. The rationale for including Grade 5 learners was to study the progression in reading ability from Grade 4 to Grade 5, given the transition of learners in the language of learning and teaching (LOLT) in Grade 4.

As with the other international achievement studies, South African learners fared poorly, achieving the lowest score of all 45 participating education systems. South African Grade 4 learners achieved an average score of 253 and Grade 5 learners an average score of 302. While the difference between the Grade 4 and 5 scores indicated some improvement in reading achievement from one grade to the next, these scores were significantly below the international average score of 500 fixed for the reading literacy of Grade 4 learners (Howie et al., 2006). A significant finding of the PIRLS study was that only a small number of South African grade 4 and 5 learners had a basic literacy and were able to retrieve information expressed literally in a text. (see Graph 2 below for the results of the 2006 PIRLS study)



Source: PIRLS, 2006

Graph 2: International Results of the PIRLS study, 2006

Only 13% of South African grade 4s could actually retrieve literal information in texts – as opposed to international performance at 94%.

2.4.2.4. THE SACMEQ STUDIES

The second Southern African Consortium for Monitoring Educational Quality (SACMEQ II) project, which was conducted between 2000 and 2002, assessed the Reading and Mathematics skills of Grade 6 learners in 14 countries in east and southern Africa. South African learners wrote the test in English since this is the LoLT for the majority of learners from grade 4 onwards. They achieved just under the mean SACMEQ score in both Reading and Mathematics, ranking eighth and ninth respectively (SACMEQ, 2005).

The current South African policy stipulates that no learners should repeat a phase more than once. The SACMEQ data indicated that about 15% of learners were exceeding this benchmark and that the levels of repetition prevailing in 2000 were detrimental for both learners and their peers.

The results of the SACMEQ II (2000) reading achievement are set out in Tables 1 and 2 below.

Table 1: Percentage of Grade 6 pupils at each level (Source: Department of Education, 2003c and 2005d)

Level 1	Pre Reading	12.2 %
Level 2	Emergent Reading	18.8 %
Level 3	Basic Reading	19.1 %
Level 4	Reading for Meaning	16.0 %
Level 5	Interpretive Reading	9.4 %
Level 6	Inferential Reading	7.0 %
Level 7	Analytical Reading	10.9 %
Level 8	Critical Reading	6.6 %

Table 2: Average Pupil Reading Test Scores and Percentage of Pupils Reaching the minimum Reading Level ((Source: Department of Education, 2003c and 2005d)

School System	Mean Score	% Reaching Minimum Reading Level
Western Cape	629	86
Gauteng	576	68
KwaZulu Natal	518	46
South Africa	492	37
Northern Cape	470	32
Free State	446	18
Eastern Cape	444	20
Limpopo	437	16
Mpumalanga	428	14
North West	428	11

The review of both the national and international evaluation conclusively reveals that South African learners are below the expected standard in their literacy and numeracy skills.

The highest enrolment of any subject in the National Curriculum Statement (NCS) is English as a First Additional Language. In 2007, 490 404 out of 564 775 grade 12 learners (i.e. 87%) wrote this subject (DoE, 2007). The majority of learners undergo most of their schooling and are being assessed in English as their second language. Attention, therefore, should be paid to issues of language, in particular First Additional Language English, when considering the readability of school textbooks.

2.4.3. THE LANGUAGE POLICY IN SOUTH AFRICAN SCHOOLS

In reviewing literature pertaining to readability and reading levels the findings of the Committee appointed by the Minister of Basic Education to review the implementation of the NCS is of importance. It highlights the difficulty of finding a benchmark for the reading level of grade 10 learners and also supports the assumption that these learners studying science, itself considered a 'foreign language', are ill-prepared for the language demands.

In July of 2009, the Minister of Basic Education, Minister Motshekga, appointed an expert panel to investigate the nature of the challenges and problems experienced in the implementation of the NCS. She requested that the panel develop a set of recommendations designed to improve its implementation.

The committee found that there had been widespread confusion as to exactly when the LoLT should be introduced in schools as the language policy specified in the Revised National Curriculum Statement (RNCS), had never been communicated nor implemented. The language policy as interpreted in the RNCS states that it is preferable for children to learn in their home language in the Foundation Phase but that they should get a solid foundation in the LoLT (in most cases English) as a subject from grade 1. However, many schools across all provinces continue to delay the teaching of English until grade 3, based on Curriculum 2005 (C2005) provincial policies, leaving children unready for the change to English as the LoLT in grade 4. Teachers' reports and research show that many schools are delaying the introduction of English until Grade 3 – the year before learners are expected to learn through the medium of English (Prinsloo, 2009). Furthermore the quality of both mother tongue and English instruction in the early grades has been questioned (de Klerk, 2000).

2.4.3.1. CURRENT RESEARCH INTO THE LANGUAGE PRACTICES OF TEACHERS TEACHING IN A SECOND LANGUAGE

In addition to those findings of the Review Committee the research of Margie Probyn (2006) is also of interest. She undertook research into the classroom practices of teachers teaching science through the medium of English as an additional language. She noted that the majority of learners did not have the necessary English language proficiency to successfully engage with the curriculum and that teachers were frequently obliged to resort to using the learners' home language to mediate understanding. In the Eastern Cape Province, where this research was conducted, Xhosa is the home language of 83.8% of the population and English speakers comprise only 3.7%. Furthermore the majority of African learners in township and rural schools (over 80% of learners) have little exposure to English outside the classroom, apart from television and popular music. She notes that "research confirms the common sense assumption that African learners use their home language in their homes and communities and demographics suggest that they have little direct contact with home language English speakers, as these comprise only 9% of the population" (Probyn, 2003:2). It appears that the majority of learners have limited access to reading materials: a national survey found that only 10% of parents bought newspapers and magazines; more than 50% indicated they had access to fewer than 10 books (Strauss, 1999: 25); and 83% of schools have no libraries (Bot & Shindler, 1997: 80–81).

Probyn (2004) argues that the resulting poor English language skills of the majority of learners in township and rural schools militate against teachers and learners strictly adhering to English. She notes that teachers are unable to adhere strictly to English because of the gap between learners' English proficiency and the linguistic demands of learning through the medium of English and the gap between the intended and enacted language policies (Probyn *et al.*, 2002).

Outside the major metropolitan areas of Gauteng province, where township schools are truly multilingual, the typical linguistic scenario is that of a school community where the majority of learners and teachers share a common home language (Heugh, 2002: 185). For instance, in the Eastern Cape, 88% of Grade 8 learners and 82% of Grade 8 teachers are Xhosa home language speakers (EMIS, 2001). Research evidence is that in such schools the *lingua franca* amongst teachers and learners is their common home language, with the use of English confined to the classroom (Probyn *et al.*, 2002).

Two small-scale research studies (Probyn, 1995; Probyn, 2001) confirm anecdotal evidence that in such schools, even inside the classroom, learners tend to use their home language with their classmates and to a greater or lesser extent with the teacher, depending on the teacher's personal views on the matter. The relative amounts of English and home language used by teachers in these studies differed quite markedly between teachers. As is widely reported in South Africa (Macdonald, 1990; Setati *et al.*, 2002) and in other contexts where a former colonial language is used as the language of learning and teaching (for examples see Arthur, 1994 in Botswana; Lin, 1996 in Hong Kong), teachers code-switched from English to the learners' home language for a range of purposes:

- to explain new concepts,
- to clarify statements or questions,
- to emphasise points,
- to make connections with learners' own contexts and experience,
- to maintain the learners' attention with question tags,
- for classroom management and discipline,
- for affective purposes.

Thus for many township and rural learners, the oral language of the school and classroom is their home language, whereas the language of reading, writing and assessment is English. The difficulty for many such learners is to bridge the gap and acquire not only proficiency in English, but also the kind of cognitive academic language proficiency (see Cummins, 2000) required for academic learning and meaningful engagement with the curriculum.

2.4.4. ALIGNMENT OF TEXTBOOKS TO THE PRESCRIBED CURRICULUM AND THE PROVISIONING OF TEXTBOOKS

Textbooks are not written in isolation but are guided by a national curriculum. In 1989 Seguin, a UNESCO expert on educational issues in developing countries, (especially in the domains of teacher training, curriculum and school textbooks) prepared a guide: *The Elaboration of School Textbooks – a Methodological Guide*. He comments that since Education for All was first introduced in a few countries and then later recognized as a

universal right, the generalized use of textbooks has become mandatory in ensuring the effectiveness of instruction and success at school (Seguin, 1989: 4).

He further adds that once generalization of primary education has been defined as a priority target by a developing country, the problem of the prerequisites for its attainment arise, namely: to build schools, train teachers, adapt curricula to development objectives and multiply didactic resources, in particular school textbooks. For the majority of countries faced with this problem, the financial and human resources required for the task are excessive and choices have to be made. Teacher training has most often been given priority (Seguin, 1989:5).

However, despite the fact that the training of teachers provides increased access to school for learners, it has not resolved the problem of the output of educational systems, which is conspicuous in the high percentage of pupils repeating a year or dropping out altogether. He suggests three main causes, one of them being the lack of instruction materials, notably textbooks, which when they do exist, are insufficient in number and not adapted to local needs.

Seguin emphasizes that efforts to train teachers prove to be inadequate when there is a lack of good textbooks to support the learning-teaching process.

He notes that that the projects undertaken by developing countries follow a distinct order: adaptation of curricula, retraining of teachers and production of textbooks. He links these projects, stressing one typically follows on the other and that without rigorous planning and coordination of the three projects, the development and production of textbooks is likely to produce serious defects. The defect of note for the purposes of this study on readability is that unsuitable textbooks will be produced if their elaboration is not coordinated with that of curricula. He states that: "Renewal of curricula and teaching programmes should precede the elaboration of manuscripts of textbooks by approximately two years so that the latter faithfully reflect the objectives and content of programmes" (Seguin, 1989:8).

The recommendations by the committee commissioned by the South African Minister of Basic Education (see section 2.4.3. and 2.4.5.) to review the shortfalls of the current South African curriculum, support Seguin’s advice and recommend a period of “18 months to three years to focus on creating tighter links between curriculum, training and LTSM” (DoE, 2009:16).

2.4.5. FINDINGS OF THE TASK TEAM FOR THE REVIEW OF THE IMPLEMENTATION OF THE NATIONAL CURRICULUM STATEMENT THAT AFFECT THE READABILITY OF TEXTBOOKS

The review document: *Report of the Task Team for the Review of Implementation of the National Curriculum Statement* (DoE, 2009) (see section 2.4.3. for an introduction to this document) prepared for the Minister of Basic Education at the end of 2009 fundamental shortcomings in the NCS that directly affect the readability of texts prepared for grade 10. A short summary of these findings now follow.

Firstly, there is a lack of articulation between the curricula of the Further Education and Training (FET) band and General Education and Training (GET), rendering the transition between the two bands difficult for both students and teachers. There is a far greater subject knowledge required for the beginning of grade 10 than is currently being provided for at the end of grade 9 (DoE, 2009:39). Teachers reported that when required to teach learning areas in the GET band they generally concentrate on what they know best. Natural Sciences was raised as particularly problematic, with teachers in the GET band concentrating on the Life Sciences and on Matter and Materials at the expense of the more difficult concepts required for the introduction to Physical Science in grade 10.

This knowledge deficit will significantly impair the readability of grade 10 physical science textbooks, as the authors have prepared them with the expectation that learners have sufficient background content knowledge required at grade 10 level. This is clearly not the case.

Secondly, teachers across all the provinces reported that textbooks were often of uneven quality and insufficiently provisioned to provide for all learners. The review team argues that the production of excellent textbooks clearly aligned to the curriculum is a priority (DoE, 2009:16) adding that an aversion to textbooks by teachers (Taylor, 2008) is another of the issues that stems from *Curriculum 2005*. The idea that a single good textbook can be followed from start to finish has become anathema to many teachers. The review team continue with the assertion that textbooks are crucial in supporting the implementation of curriculum as these aid curriculum coverage, and make available the conceptual logic of the subject in question as it progresses through the set field of knowledge to be taught and learnt. The textbooks also offer a crucial resource for teachers in planning and in gaining access to the appropriate knowledge and skills to teach, at the appropriate level. The review team concluded with “a reassertion of the importance of (good) textbooks will assist teachers in implementing the curriculum” (DoE, 2009: 25).

The review team introduced their findings on textbooks and learning and teaching materials (LTSM) with the following comment (DoE, 2009:51) from Taylor (2008): “A good textbook contains, in a single source, a comprehensive study programme for the year - it lays the curriculum out systematically providing expositions of the concepts, definitions of the terms and symbols of the subject in question, worked examples of standard and non-standard problems, lots of graded exercises, and answers”. They continue by noting that both national and international research has repeatedly underscored the role of the textbook as one of the most effective tools through which to deliver the curriculum and support assessment. Not only can it ensure curriculum content and assessment coverage, but it can also offer appropriate pacing and weighting of content and assist teachers with lesson and year planning. This is especially important during periods of curriculum and assessment reform (DoE, 2009: 51).

Finally, the current curriculum content documents lack clarity, are sometimes contradictory and are difficult to navigate (DoE, 2009:19-20). The review team refers to these documents that guide teaching and the preparation of LTSM as not being ‘user friendly’ (DoE, 2009:20). The Guidelines in the NCS Physical Sciences: Content Document (DoE, 2006), the document that guided the authors and editors of the grade 10 textbooks which are the

subject of this study, left much to the individual writer's discretion with regard to content. The document allows 'space' for educators (and writers) to make choices (DoE, 2006:14), with a vague inference that these choices be made 'in relation to their own knowledge' (DoE, 2006:14). The document further states that National policy expects that educators will design their own curricula and thus the chemistry statements give guidelines only. With respect to the depth to which the text or lesson plan should go, the NCS Physical Sciences: Content Document (DoE, 2006) refers to a 25 year gap between 'school chemistry and chemistry' and suggests that the OBE context should guide any interpretation of the depth of content.

2.5. REVIEW OF RECENT SOUTH AFRICAN RESEARCH INTO SCHOOL TEXTBOOKS AND THEIR READERS

Research on the effectiveness and readability of school textbooks in South Africa remains a neglected area, in spite of it being acknowledged (Braslavsky, 2006: 36) that "Textbooks will remain an instrument of extraordinary power . . . the most effective of educational technologies yet invented, and there is no reason to imagine a modern educational system where textbooks do not play a central role."

Roger Seguin in the Preface to a textbook guide commissioned by UNESCO (Seguin, 1989), noted that the problem which many countries still face today is that of ensuring the provision of school books to their educational system. He said that this is an undertaking which demands considerable resources given the complexity of the different operations involved in the production and distribution of school books. UNESCO has promoted a series of regional meetings on the theme which have offered the countries directly concerned recommendations on aspects related to costs, management, production planning and the distribution of school textbooks. However, besides these very important and decisive aspects, he adds that one of the main objectives of educational authorities is to provide textbooks which are "adapted to the social and cultural context of their countries and which meet the needs of their educational system" (Seguin, 1989: Preface).

Yet there remains a dearth of textbook research in South Africa and the publishers of school textbooks face time constraints that seriously inhibit their efforts to pilot books in classrooms before publication. Indeed, the curriculum written for the content subjects in the FET band of C2005, the RNCS and NCS was only made available to the publishers three to four months before the deadline for the submission of textbooks.

David Langan (1990) extensively studied the use of geography textbooks in black primary schools in the mid-1980's and argued that these textbooks were a major source of difficulty in the teaching and learning of geography. He noted that in these schools, children began their education through the medium of their mother-tongue or home language; the medium of instruction for the first four years of their schooling. English was introduced as a curriculum subject in the second year of schooling, before learning skills had properly been established in the mother-tongue and was usually taught by non-native speakers. He noted that between, what was then Sub B (grade 2) and Std 2 (grade 4), the average learner would have received little more than 365 hours of what was less than adequate formal English instruction (van Rooyen, 1990:1).

The current situation differs little from when Langan conducted his study except that learners typically make the transition to English one year earlier (in grade 4 rather than grade 5), and even less time is spent learning English in the preceding three years than was formerly the case. As noted in section 2.4, language policy documents have been obscure, resulting in varied practice among teachers, and more often than not, children have received little or no instruction in English during the first three years of primary school. In the fourth year of schooling, the learning areas increase dramatically, from three to eight, and many of the textbooks for these subjects are written in English or Afrikaans, the recognised LoLT.

The assumption that the learners' English competence was such that they would be able to learn the content subjects of Mathematics, General Science, History, Geography and Health Education in English was seriously challenged at the time of Langan's study. He quoted Lanham who argued that what was known by pupils in their first year of English medium instruction:

...is a product not of natural assimilation, but of being taught it in the previous three years of schooling. For the great majority of primary school children, English learnt in the classroom lacks any sustaining environment outside the school; in other words, a foreign language.

Lanham (1986:1)

Langhan noted the need for further research in the field of primary school English medium content subject instruction, adding that research was focused around secondary school level in an “extended but largely unsuccessful attempt to reduce black matriculation failure rates and improve school leavers’ qualifications” (1990:1).

Macdonald, in her study of General Science textbooks (1986:5), reported that the challenge faced by the pupils was two-fold: the first was their poorly developed English language competence and the second, the quality of the content subject textbooks they would be likely to use. The Review Committee for the Minister of Basic Education (2009) highlighted the problem caused by the gap between grade 3, with only three learning areas, to that of eight in grade 4. Grade 4 is also the year in which the learners first learn through English LoLT. The situation studied by Macdonald, where she mentions that children meet expository texts for the first time in the former Std 3 (grade 5), differs from today’s in that the children now meet these expository texts a year earlier, in grade 4. Until grade 3, the only books that children are exposed to are their reading books. In grade 4 they receive up to 5 textbooks, each in excess of 100 pages in length.

Macdonald reported a similar situation in 1986, adding that the children faced at least three other obstacles:

- difficult grammatical constructions;
- a rapid increase in vocabulary, moving from a maximum expected vocabulary of 700 words in Std 2 (grade 4) to 7000 demanded by the Std 3 (grade 5) textbooks;
- textbooks were badly constructed.

She felt that the child’s task verged on the impossible and added that “children’s failure to grasp the language of the simplest and best written lessons in prescribed content subject textbooks probably indicate that they were unable to make any real use of their textbook, even with the teacher’s aid” (pg. 2).

2.6. THE CONTEXT IN WHICH THE TEXTBOOK IS READ

Wellington and Osborne (2001: 41) lament the lack of mediation of text in the classroom and note that it is important that students are taught to read expository science text “actively, critically and efficiently”. They argue for making reading a key part of the science curriculum for two reasons. Firstly, because reading is a scientific activity and to be capable of reading carefully and critically is a vital component of being a scientist, and secondly, because the ability to read scientific discourse is a skill necessary for life-long learning.

Reading science often has to be reflective as well as receptive (Lunzer & Gardner, 1979; Bulman, 1985) and careful reading is a skill which has to be taught. Davies and Green (1984) discuss the need for the reader to be active and note three elements of active reading:

- there needs to be a purpose – readers are given specific targets, instructions and goals
- there needs to be a ‘coach’ – reading is scaffolded, guided and directed by a teacher
- there needs to be discussion and collaboration of what is read – active reading is a shared activity

The mediation of text in the classroom is very important for the developing science reader and the research into mediation of text is well-documented and extensive. However, it is beyond the scope of this research to investigate mediation in any meaningful way and it is recommended that this be kept for further research.

2.7. CONCLUSION

The review of literature, demonstrates that the readability of science textbooks can be investigated using both classical quantitative measures and qualitative cognitive-structural forms of analysis.

In particular, the aspects of expository science discourse that have dominated the cognitive-structural readability research arena are:

- the scientific language, non technical vocabulary, symbolic language and the use of nominalisation found in the texts
- the rhetorical structures underlying the scientific discourse
- the graphicacy supporting the concepts and textual features
- the activation of the reader's background and prior knowledge by the text
- the conceptual complexity of the content and the consideration given to cognitive processing, including the danger of working memory overload

Literature emphasises that reading does not occur in isolation, nor are textbooks written in isolation. The necessity of investigating both the match of the texts to the prescribed curriculum; as well as the match between the texts and the audience for which they are prepared, is clearly important when considering the relationship between readability and the texts.

The above points are foregrounded in the research methodology that follows in Chapter 3.

CHAPTER 3

METHODOLOGY

In this chapter I deal with the design of my research methodology. I outline the preliminary study that informed my orientation and choices; then discuss my reasons for choosing a mixed methods research design and locate my research pragmatically. I then document my data-gathering and analysis process in some detail and finally conclude the chapter with an overview of the threats to validity and ethical considerations in this research.

3.1. THE PRELIMINARY STUDY

A preliminary study was conducted to guide the research design and to add dimension to the research question. From the outset, a review of the literature on readability pointed to the benefits of using both quantitative and qualitative data gathering and analysis methods in investigating readability. This suggested a mixed method research design and the preliminary study was necessary to give clarity to the approach.

I conducted a preliminary study by selecting samples from all three selected textbooks and applying the Fry Readability Graph and the New Dale-Chall formula to the samples. The data gathered was quantitative. A graphic representation of the results showed a fluctuation of readability scores across the textbooks but a fairly consistent result within a particular book. The correlation between the results generated by the two formulae within a particular book revealed a consistent difference thus strengthening the validity of the results.

I then selected one of the textbooks and conducted a preliminary qualitative study of samples from the book. The qualitative sampling method included, amongst others, investigating the use of scientific language and rhetorical structures in the book together with its conceptual progression and alignment to the curriculum. These qualitative

measures are reviewed in depth in the Chapter 2: Literature Review. The results of this qualitative analysis supported the quantitative readability data gathered.

Permission was then negotiated with a school where certain of the teachers use the textbook and a focus group discussion was conducted. Questions regarding the background knowledge that learners bring to the subject, probing the effectiveness of the textbook, its shortfalls and strengths were discussed. Following the focus group discussion, letters of thanks were sent to the participants and a shortlist of further schools and teachers was made. The selection of schools and teachers is discussed (see section 3.3.1.) under data gathering.

I then made contact with the author of the textbook as well as the commissioning editor, requesting permission for an interview. This was semi-structured in form and its purpose was to gain insight into the challenges that the producers of the textbooks face when trying to assure readability for a South African audience.

The combined result of the quantitative application of readability formula, qualitative textual analysis and data from focus groups with teachers using the books, guided the research design as formulated in the following sections of this chapter.

3.2. A MIXED METHODS DESIGN

Readability as defined for this research study, is concerned with the relationship between certain variables. The preliminary study suggested that addressing and examining these would be advantaged by using both quantitative and qualitative data gathering and analysis 'tools'. Furthermore, the literature revealed that a combination of classic and cognitive readability is a constructively sound way of measuring textual difficulty (Chall, 1995:110), and thus the choice of a mixed method approach was further justified.

It was of interest to note while reviewing the literature regarding readability and its measurement, that most of the researchers used some variation of a mixed method design. In some cases, quantitative methods were embedded in qualitative method (see Chapter 2,

section 2.2.1.2.) and in others, quantitative methods helped to quantify the qualitative findings (see Chapter 2, section 2.2.5.3.1.).

Jick argues the advantages of mixing both qualitative and quantitative methods for the purposes of triangulation, as the strengths of one method offset the weaknesses of the other (Plano Clarke & Creswell, 2008:109). Therefore, the goal of this approach is generally to seek convergence between the different methods (Plano Clarke & Creswell, 2008:105). I used quantitative methods dictated by the readability formulae, relying on both the strength of their objectivity and consistency, as well as very large data bases testifying to their validity.

Triangulation is broadly defined by Denzin and Lincoln (2005) as the combination of methodologies in the study of the same phenomenon. In the case of this study, the phenomenon studied was the readability of science textbooks and the methodologies used were both quantitative and qualitative. In the Discussion of the Data phase, I integrated my two strands, triangulating the data and found that they 'connected' well with each other.

More particularly the mixed method design followed in this research is a concurrent triangulation one. Plano Clarke and Cresswell (2008: 183) state that this design is selected when the investigator makes use of two different methods in an attempt to confirm, cross-validate, or corroborate findings within a single study.

As well as being concurrent, the method used is of a convergent parallel design: I used concurrent timing to complement the quantitative and qualitative strands during the same (and single) phase of the research; prioritising the methods equally and keeping the strands independent during analysis. During the interpretation of the results, I allowed for mixing the results to get a clear overall picture.

Plano Clarke and Cresswell (2008) add that ideally, equal priority would be given to each method and in this case, the qualitative and quantitative strands are of equal importance. This design integrates the results of the two methods during the interpretation phase and it is here where convergence or divergence is noted and discussed. Below (see Figure 1) is a schematic representation of the design.

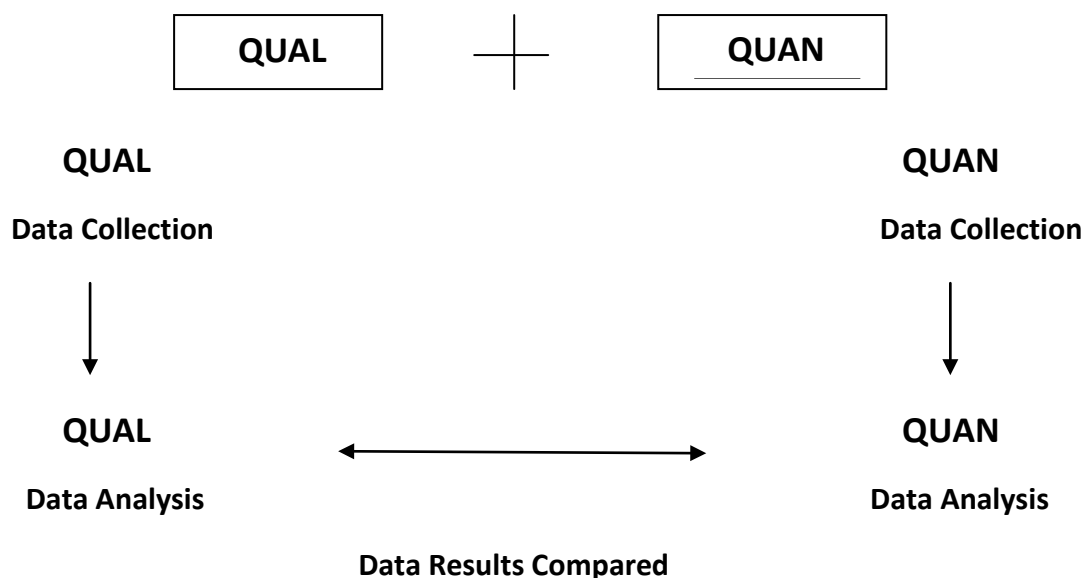


Figure 1 Concurrent Triangulation Design (Plano Clarke & Creswell, 2008:181)

The advantages of using this design, as elaborated by Plano Clarke and Creswell (2008), are that it can result in well-validated and substantiated findings, as well as facilitating a shorter data gathering period with the two collections running simultaneously. The shorter data gathering period, in the case of this study, was particularly advantageous as I was able to focus on the quantitative textual aspects of the study while waiting for an opportunity to work in schools and with teachers.

Furthermore, the mixed method design was a fixed one in that the use of quantitative and qualitative methods was predetermined at the start of the research process and the procedures were then implemented as planned.

The use and development of mixed method design is a fairly modern one that has gained in popularity where research designs rely on the strengths of each approach to provide both a complete result, as well as a more valid one.

3.2.1. PRAGMATISM AS A THEORETICAL FRAMEWORK

The incommensurability of knowledge forms has long dominated the arena of social studies research (Guba, 1990; Guba & Lincoln, 2005). Qualitative research is traditionally situated within interpretivism and/or constructivism while quantitative research is traditionally linked with positivism or post-positivism. In the 1996 edition of his landmark book, *The Structure of Scientific Revolutions*, Thomas Khun explicitly rejects the claim “that

proponents of incommensurable theories cannot communicate with each other at all” (Kuhn, 1996:198-199). He argues that there is nothing about the nature of paradigms (in the sense of shared beliefs among members of a speciality area) that inherently prevents the followers from understanding the claims of another. He adds that the essential question is how effectively the two camps can communicate with each other (Plano Clarke & Creswell, 2008:47).

David Morgan (in Plano Clarke & Creswell, 2008:53) continues the argument by claiming that there is a fundamental similarity between saying that members of a speciality area share a common consensus about which questions are worth asking and about which methods are most appropriate for answering them. A pragmatic approach denies that there is any *a priori* basis for determining the limits on meaningful communication between researchers who pursue different approaches to their field. The emphasis is on *shared meanings* and *joint actions* which Morgan describes (in Plano Clarke & Creswell, 2008:53) as being the extent that the two research fields are satisfied that they understand each other and the extent to which they demonstrate the success of shared meaning by working together on common projects.

Thus this research study is rooted in pragmatism. According to Cherryholmes (1992) and Creswell (2003), pragmatism is not committed to any one system of philosophy and reality as a mixed method researcher draws liberally from both qualitative and quantitative assumptions and freedom of choice is necessarily embraced. Furthermore, these writers add that for the pragmatist, truth is what works at the time; it is not based in a strict dualism between the mind and a reality completely independent of the mind.

I connect theory with my data, *abductively*. David Morgan (Plano Clarke et al. 2008) comments that the pragmatic approach is to rely on a version of abductive reasoning that moves back and forth between induction and deduction – first converting observations into theories and then assessing those theories through action. My relationship to the research process is intersubjective as I need to move back and forth between various frames of reference and the approach captures this duality. Inference from data relies on transferability.

My research also adopts a case study design in that it focuses on *one phenomenon* (McMillan & Schumacher, 2006:316), namely: readability and each textbook together with its educators and learners using it becomes a site. Yin (1994) noted that case study is enquiry in a real life context and further mentions that the process is particularly useful when the boundaries between phenomenon and context are not clearly evident.

The three textbooks used in the study and selected as per the convenience sampling discussed below in section 3.3.1., are:

- Case Study 1: Study and Master, Physical Sciences Grade 10, 2nd Edition 2008
- Case Study 2: Focus of Physical Sciences, Grade 10, 1st Edition 2008
- Case Study 3: Successful Physical Sciences, Grade 10, 1st Edition 2008

It is primary research in that data is gathered from primary sources, namely: the textbooks used for the teaching and learning of physical science and the experience of these by teachers using them and teaching physical science through the medium of English.

3.2.2. THE RESEARCH QUESTION

The research question: ‘how readable are the grade 10 physical science textbooks?’ warranted a more thorough examination after the pilot study and also in the light of the conceptual understanding of readability.

Readability as defined for this research study is concerned with the relationship between three variables. First there is the textbook, which is more or less readable depending upon its internal characteristics: language, organization and cognitive complexity. The second variable is the reader: his/her reading ability, language, cognition, previous knowledge, interests and purposes for reading. And third, there is the context: whether the reader receives instructional help from a teacher or knowledgeable peers, and the degree and kind of comprehension expected – whether this be the gist, thorough knowledge, or critical reaction.

Thus the research question expanded to incorporate the following sub-questions:

Pertaining to the readability of the text, I organise them according to their type:

Quantitative research questions:

- What do the quantitative measures of readability indicate about the reading level of the texts?

Qualitative research questions:

- How does the vocabulary – scientific, non-technical and symbolic - affect the readability of the textbook?
- Does the graphicacy in the text work to improve its readability?
- What is the nature of the cognitive structuring of the text and does this aid or impair readability?
- What part does the cognitive complexity of the text play in raising or lowering the readability for the selected grade level?
- Does the alignment of the book to the curriculum affect its readability?

Pertaining to the reader and his/her reading ability, language, cognition, previous knowledge and interests and purpose for reading, the following sub-questions were asked. Again I categorize them:

Quantitative:

- How well are readers of the books likely to comprehend the non-technical science terms?

Qualitative:

- How is the literacy level of the readers likely to affect readability of the books?
- What background knowledge are the readers likely to bring to the text and how might this affect readability?

The third variable affecting readability is the context in which the book is likely to be read. For the purposes of this study, the question was only addressed through the focus-group discussions and the data generated by these.

To sum up, in my mixed methods research design, I:

- gathered and analyzed rigorously both qualitative and quantitative data (based on the research question);
- mixed (or integrated) the two forms of data concurrently by combining;
- gave priority to both forms of data (in terms of what the research emphasizes);
- used these procedures in a single study;
- framed these procedures within philosophical worldviews using specific theoretical lenses;
- combined the procedures into a specific research design that directed the plan for conducting study

3.3. DATA SAMPLING

The mixed method design, having concurrent qualitative and quantitative strands, required three different sampling techniques:

- convenience sampling with respect to the initial choice of textbooks used in the study as well as the schools participating in the study
- probability Sampling with respect to the quantitative data gathering
- purposive sampling with respect to the qualitative data gathering

Each of the three sampling techniques is now detailed below.

3.3.1. CONVENIENCE SAMPLING AND THE CHOICE OF SITES OF STUDY

Convenience sampling involves drawing samples that are both easily accessible and also willing to participate (Plano Clarke & Creswell, 2008:206), and the initial sampling approach with respect to the textbooks is to some extent convenience sampling. As there are eleven textbooks in the recommended DoE book (DoE, 2008) catalogue and as it was impossible,

within the scope of this study, to examine all eleven, a selection was necessary. I made contact with the physical science teachers in the English secondary schools in the region where I work and ascertained which textbooks they were using. The three most frequently used textbooks were selected for this study.

It followed then that the choice of schools to participate in the focus group discussions would necessarily be those where the textbooks chosen, are used. Here my choice was narrowed somewhat as many of the secondary schools in the surrounding 500km radius of my own school have Afrikaans as the LoLT. I was analysing English textbooks, so directed my focus to English schools and selected one in which the learners are native English speakers and two in which the learners have Xhosa as a home language but English as the LoLT.

The teachers in these schools willingly participated in the focus group discussions. They were also willing to test the comprehension of the non-technical words by the learners in their classes.

3.3.2. PROBABILITY SAMPLING (QUANTITATIVE DATA GATHERING)

Probability sampling is succinctly summed up as a technique involving “selecting a relatively large number of units from a population, or from specific subgroups (strata) of a population in a random manner where the probability of inclusion for every member of the population is determinable (Tashakkori & Teddlie, 2003:713). I used probability sampling, and more specifically stratified probability sampling, to select the quantitative data used in my study.

The NCS Physical Sciences Grade 10 -12: Content Document (DoE, 2009) breaks the chemistry component of the syllabus into three knowledge areas (KAs) namely: Matter and Materials, Chemical Change and Chemical Systems and I was interested to see if the readability was constant across the sections of a textbook and so the sampling was equally distributed amongst all three. Furthermore, I used the sub-headings of the curriculum guidelines, to structure my sampling within a KA. I sampled the section under each sub-heading. This gave me nine samples per section and twenty seven samples per book. As explained, I used all three readability measures in my sampling.

Using probability sampling in this way, I aimed to achieve representativeness and have a sample that accurately represented the entire population; which in this case was firstly the readability of each KA and then these as a sub-set of the textbook.

The manipulated variable was the textbook; the responding variables were the readability and reading ease levels according to the Fry graph, New Dale-Chall and the Flesch formula. Control variables were the specific science course, the grade level recommended by the Department of Education and the edition of the textbook.

Procedural controls included:

- using only DoE recommended textbooks (see Appendix A)
- comparing only the latest published edition of each textbook
- using an appropriate sampling method as discussed above
- verifying the number of words, sentences, and syllables before doing computations
- applying the same three measures to all the textbooks
- having the same researcher, myself, perform the selections and apply the quantitative measures

The formula was applied to each book in turn, before the second and then third formula was applied. The same samples were used each time.

3.3.3. PURPOSIVE SAMPLING (QUALITATIVE DATA GATHERING)

My textual qualitative data sampling technique was purposive. This type of sampling is defined as selecting units based on specific purposes associated with answering the research study's question (Plano Clarke & Creswell, 2008:200-201). As I was interested to note how the authors introduced the readers to chemistry and as I wanted to analyse exactly the same section in each textbook, I analysed the first two paragraphs under the section Matter and Materials in the first KA of the chemistry section of each book.

Furthermore, I was also interested to analyse the more conceptually difficult areas in chemistry as highlighted in the literature review and so specifically sampled these in the text:

- the writing of chemical formulae
- bonding of elements

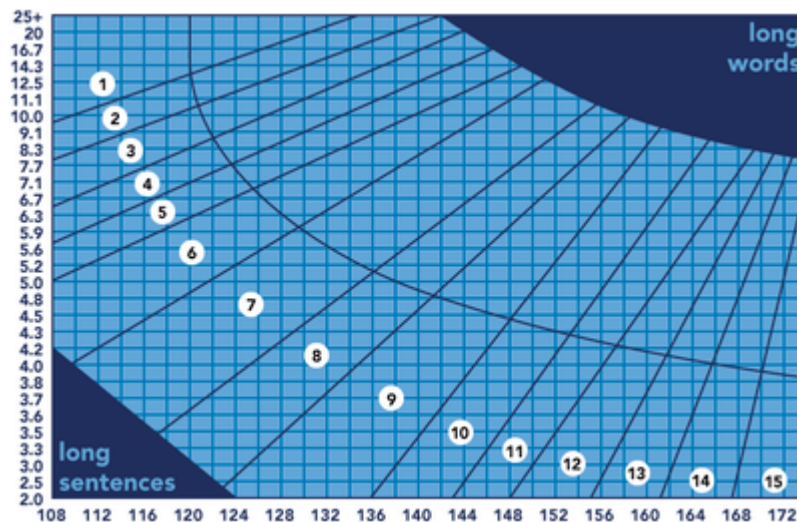
3.4. QUANTITATIVE DATA GATHERING – USE OF THE READABILITY FORMULAE

The relationship between the readability of the textbook and its semantics (vocabulary and sentence length) can be investigated using credible readability formula. These have been comprehensively reviewed in Chapter 2, and are a valid base for examining readability quantitatively.

I used three standardised readability instruments namely: the Fry Readability Graph, the New Dale-Chall Readability Formula and the Flesch-Kincaid Reading Formula. To improve the accuracy of the study, the three readability methods incorporated two different readability measures: two that made use of formulae and one that utilized a graph.

A brief description of each now follows.

3.4.1. FRY READABILITY FORMULA



Average number of syllables/100 words

A rendition of the Fry Graph

The grade reading level (or reading difficulty level) is calculated by the average number of sentences (y-axis) and syllables (x-axis) per hundred words. These averages are plotted onto a specific graph; the intersection of the average number of sentences and the average number of syllables determines the reading level of the content.

The grade level score is calculated by selecting separated 100 word passages and counting the number of syllables in the sample. The number of sentences in the sample is then counted, estimated to the nearest tenth. Finally the average sentence length and average number of syllables are plotted against each other as described above.

3.4.2. THE NEW DALE-CHALL READABILITY FORMULA

The grade level or readability level is calculated by means of a formula. The following steps are applied:

1. A 100 word sample is selected.
2. The average sentence length (ASL) is computed by dividing the number of words by the number of sentences.
3. The percentage of words (PDW) not on the list of 3000 familiar words is computed.

4. Using the tables – both reading level tables and cloze score tables – the reading level of the sample is then read off. For example a sample with 34% unfamiliar or difficult words and an ASL of 6, would give a reading grade level ranging between 13 and 15.

3.4.3. THE FLESCH-KINCAID READABILITY FORMULA

The Flesch-Kincaid Reading Formula (FKRF) also uses one-hundred-word samples. The average sentence length is computed by dividing the 100 word sample by the number of sentences in the sample (ASL), and the average number of syllables per word is computed by dividing the number of syllables in the sample of words by 100 (ASW). These averages are then transferred to the following formula to give an appropriate reading level:

$$\text{Grade Level} = (.39 \times \text{ASL}) + (11.8 \times \text{ASW}) - 15.59$$

The Flesch formula has correlations as high as .98 with other reading formula.

3.4.4. FORMULA DISCREPANCIES

The discrepancy between the scores of different formulae is often cited by critics as an indication of their lack of precision (DuBay 2004:54). However, what is important is not how the formulae agree or disagree on a particular text but their degree of consistency in predicting difficulty over a range of graded texts.

The formulae used in this study – like reading tests – simply do not have a common zero point (Klare 1982). They are based on combinations of different variables as described in the above section as well as different criterion scores used in their development. This criterion score is the required level of comprehension indicating reading success as indicated by the percentage of correct answers on a reading test. For example, a formula can predict the level of reading skill required to answer correctly 75% of the questions on a reading test based on a criterion passage.

The formulae developed with the higher criterion scores tend to predict higher scores, while those with high validity correlations, for example, Dale-Chall and Flesch, tend to predict lower scores. The Flesch and the Dale-Chall formulae use a 75% score.

Finally, the range of scores provided by different formulae, are reminders that they are not perfect predictors. They provide probability statements or rather estimates of difficulty (DuBay, 2004:55).

3.4.5. THE PROBLEM WITH OPTIMAL DIFFICULTY

Different uses of a text require different levels of difficulty. Bormuth (1967) indicated that the 35% close score was the point of optimum learning gain for assisted classroom reading.

This is in tune with Vygotsky's (1978) claim that when learning is mediated by a teacher, optimal level of difficulty is slightly above a learner's current level of development and not below; it is within what Vygotsky termed the zone of proximal development. Thus materials intended for assisted reading when a teacher is available should be somewhat harder than the readers' tested reading level.

Paul (2003) found that independent reading requires at least 92% comprehension for advanced readers.

3.4.6. QUANTITATIVE DATA GATHERING : THE COMPREHENSION OF NON-TECHNICAL VOCABULARY

Quantitative data collection was also used when assessing the understanding of the learners using reading the non-technical vocabulary found in the textbooks. Earlier studies reviewed in Chapter 2, had shown certain words, to be as problematic in the comprehension of science language as the scientific terminology itself. A multiple choice questionnaire testing these words, [similar to that used in prior studies (Appendix C)] was

given to 300 learners in three schools. These learners all actively use the textbooks being studied. The data was then analysed as follows:

The Facility Value (FV) was computed: that is the fraction of the class making the correct choice. I used the results from two first language English classes (n=60) and six second language English classes – home language being Xhosa (n=360). The two groups were then compared in the following way:

Secondly, the commonest distracters were determined. These are the commonest wrong word chosen.

In taking the results to my textbook analysis, I highlight the continual use of this non-technical vocabulary and stress the need to support it in teaching and in the text.

3.5. QUALITATIVE DATA GATHERING

The questions that could not be answered quantitatively were:

- How is the literacy level of the readers likely to affect readability?
- What background knowledge are the readers likely to bring to the text and how might this affect the readability?
- How is this text likely to be mediated in the classroom?
- What is the kind of comprehension necessary?

The tools used in the qualitative data gathering were both text line-by-line analysis of the texts as well as focus group discussions with teachers using the texts.

3.5.1. FOCUS GROUP DISCUSSIONS

The goal of focus-group discussions is two-fold; it aims to elicit information on a specific topic as well as to seek an in-depth understanding of the meanings developed by the actors within the group setting (Vaughn, Schumm & Sinagub, 1996; Schurink, Schurink & Poggenpoel, 1998; Berg, 1998; Southwood, 2000; Babikwa, 2003). The assumption is that actors are valuable sources of information and that, within a relaxed environment, a more in-depth understanding of issues can be obtained (Vaughn *et al.*, 1996:17). Focus-group

discussions were a very important part of qualitative data collection. The opinions of the teachers using the textbooks being analysed, as well as their knowledge of the learners taking Physical Science in grade 10, was invaluable and a rich source of data.

That textbooks and their effectiveness, are close to the heart of the participating teachers, was very obvious from the strength of their participation during the discussions. Babikwa (2003:59) emphasizes that the issues discussed in a focus group should be of mutual interest to the co-researchers. The suggestions made by Davies (1999:105), that the researcher should take the role of the key actor and should ensure that the other actors are given a *voice* (Wellington, 2000:72) in the process, was put into practice in the focus-group discussions for this research. The focus-groups were small, comprising the 'science department' of a school and this resulted in the discussions being in-depth and also allowed each teacher to give his/her opinion liberally.

One of the characteristics that distinguishes focus groups from other qualitative interview procedures is the dynamic and interactive group discussion (Vaughn *et al.*, 1996; Cohen *et al.*, 2000). The transcripts of the discussions held bears testimony to the lively interactive nature of these as well as the richness of data gathered, as the teachers sought to give voice to their concerns and challenges of using the texts in the classroom. Cohen *et al.* (*ibid*:288) argue that actors' views emerge from interaction during focus groups and as such, the synergy may allow solutions to problems to be generated collaboratively (Berg, 1998:101 - 4). The teachers felt at ease to make suggestions as to what would help in making the textbooks more readable and those teaching learners in their second language were particularly enthusiastic in their input.

Southwood (2000:51) adds that "the synergetic effect from the focus group can encourage people to open up more, freeing people up to be more honest and critical." As Lotz (1996:96) suggests, during focus-group discussions, interaction between participants should be informal to stimulate in-depth discussion and reflection on the topic. According to Morgan (cited in Davies, 1999:105):

The hallmark of focus groups is the explicit use of group interaction to produce data and insights that would have been less accessible without the interaction found in a group.

It is recognized, however, that while the focus-group approach may be conducive to productive discussions, the group dynamics can pose challenges for the researcher (Southwood, 2000:51). However, in this study the issues discussed were not of a sensitive nature and the teachers were generally unanimous regarding issues and problems experienced.

3.5.2. TEXTUAL ANALYSIS

3.5.2.1. VOCABULARY USED IN THE TEXTS

I analyzed the scientific vocabulary using Wellington and Osborne's (2001) taxonomy of science words (see Chapter 2, section 2.3.1.). I took note of the non-technical and general vocabulary, analyzing whether efforts are made in the texts to support meaning and enhance comprehension.

3.5.2.2. GRAPHICACY AND LAYOUT OF THE TEXT.

Both graphicacy and layout affect readability and each textbook was individually analysed as to the layout. Drawings and photographs were analysed to see if they were supported by the accompanying texts and if they played a role in lowering the reading level of the text.

Focus-group discussions with the teachers also revealed needs regarding this aspect of readability.

3.5.2.3. RHETORICAL STRUCTURING OF THE TEXT

I analyzed the rhetorical structuring of the selected samples to determine whether it aided or retarded the readability of the text. I also looked for any reference to rhetorical structuring during the focus group discussions.

3.5.2.4. PRIOR KNOWLEDGE ACTIVATION BY THE TEXT

The texts continually rely on background knowledge and I analysed them, highlighting where the understanding of a particular concept was dependent on work done in the previous grades. I then relied on the focus group discussions to give me an indication of the background knowledge the learners are bringing to the subject.

Motivation is also difficult to assess and here I again relied on the teacher's 'reading' of his/her class and the affect that lack of motivation has on the assessed readability.

Examination of each of the facets comprising readability takes place using the data gathering technique best suited to it. Reliable and credible readability measures give an overall indication of the readability level of the textbooks: the data gathering and analysis of this is quantitative. The general understanding of the non-technical language of the learners using these books is also ascertained quantitatively.

The background knowledge of the learners cannot be measured quantitatively but this is investigated qualitatively through the focus group discussions with teachers. The type of difficulties regarding mediation of the text for this study was also gained qualitatively.

3.5.2.5. CONCEPTUAL COMPLEXITY

Conceptual complexity of the textbook was investigated by analysing the cognitive load (see Chapter 2, section 2.2.5.), the multi-level learning manipulations required to understand the text and whether the texts were considerate of WMC and avoided cognitive overload.

3.5.2.6. ALIGNMENT OF THE TEXTBOOKS TO THE CURRICULUM

The alignment of the books to the curriculum is also important in the context of this study and using the NCS Physical Sciences: Content Document (DoE, 2009) as a reference, I analyzed selected samples of the textbooks to determine how closely they are aligned to the above mentioned document.

Focus-group commentary also gave valuable insight into how well the teachers felt the books were aligned to the curriculum and what their strengths and weaknesses in this respect were.

3.6. VALIDITY OF THE RESEARCH.

Tuckman (1978), in discussing validity, examines two principles: internal validity and external validity and further comments that both are important to the overall validity of a study. He mentions that a study is credited with internal validity if the outcome of the study is a function of the approach being tested rather than the result of other causes not systematically dealt with in the study. In other words, internal validity affects our certainty that the research results can be accepted based on the design of the study.

A study has external validity if the results obtained would apply in the real world to other approaches. In other words, external validity affects our ability to credit the research results with *generality* based on the procedures used.

When considering internal validity it is important to establish that the method chosen can reasonably measure the readability of the textbooks. In Chapter 2, the literature regarding both quantitative and qualitative readability measures show that they have been well researched by a broad community of scholars and provide a valid method of researching readability both quantitatively and qualitatively.

The analysis of the quantitative data was done using descriptive statistics. The measures of central tendencies, most importantly the mean readability of each book and then the distribution shape of readability data through the knowledge areas, constitute the research findings.

The issues of validation and verification are important and these are addressed using a careful sampling method to avoid bias and then applying more than one standard readability test so that correlations can be made and results cross checked.

The validity of the quantitative data analysis is also assured by cross-checking the sampling, measurement of variables, substitution of variables into respective readability formulae and mathematical calculations.

The validity of the qualitative data is established by member-checking by critical friends and other researchers in the field of education. I sent samples of my qualitative data analysis to various researchers in the field of science education requesting their critical assessment of these pieces. The verification and the feedback from these science education researchers is included in Appendix C.

I critically analyzed the focus-group discussion notes and transcripts looking for further supporting evidence of the quantitative and qualitative conclusions drawn from applying the readability formulae and the textual analysis. Critical analysis of the transcripts of interviews of the editors of the books in question also sheds light on possible reasons for the readability measured in the textbook.

3.7. ETHICAL CONSIDERATIONS

Informed consent is essential when collecting data (Cohen, Manion & Morrison, 2000) and I was transparent as to the nature of my research. I sought written permission from the principals of the schools where my research sites are based as well as informed consent from the science teachers. I have also taken care to keep the identity of the participants anonymous.

The raw data generated by my research is catalogued and kept confidential, protecting the anonymity of my participants.

CONCLUSION

As reviewed in the literature on readability research and as noted above, the relationship between the readability of a science text and the text itself can be comprehensively investigated using both classical quantitative measures and a qualitative cognitive-structural form of analysis.

In the analysis of the data that now follows, the readability of the textbooks are quantitatively investigated.

The cognitive-structural analysis continues with particular emphasis given to the following aspects of expository science discourse that impact the readability of the texts:

- the vocabulary used in the texts
- the rhetorical structures underlying the discourse
- the graphicacy supporting the concepts and textual features
- the activation of the reader's prior knowledge by the text
- the conceptual complexity of the content and the consideration given to cognitive processing, including the danger of working memory overload

Attention is also given to investigating the data on the match between the textbooks and the curriculum for which they have been written and the comprehension, by the learners, of the non-technical words used in science discourse.

As is also noted above, reading does not occur in isolation and the data generated in the focus group discussions is analysed in detail noting:

- the experience of the teachers using the textbooks
- the understanding, that the teachers have of the background knowledge of the learners and their level of literacy

CHAPTER 4

DATA ANALYSIS

This chapter is guided by the principles discussed in Chapter 3 and is subdivided into five sections: each of the three textbooks form an independent section and are analyzed separately, followed by the analysis of the non-technical language in science and the focus-group discussions with the teachers using the textbooks.

In brief, I analyze the textual data of each of the three case studies, beginning with the quantitative data and then progressing to the qualitative data. Under qualitative data, I focus on the vocabulary used in the texts, the graphicacy found in the texts and the rhetorical structure of the texts. Attention is given to the areas of conceptual difficulty and finally I consider the alignment of the textbook with the curriculum documents that guided them.

Next I analyze the quantitative results of the multiple choice test that assessed the comprehension of non-technical words by the students using the textbooks and the qualitative data gathered during the focus-group discussions with the teachers using the textbooks.

Chapter 4 is concluded by a short summation.

4.0. INTRODUCTION TO THE TEXTUAL ANALYSIS – AN OUTLINE OF THE CURRICULUM CONTENT DOCUMENT THAT GUIDED THE PREPARATION OF THE TEXTBOOKS

Before commencing with the data analysis of the three textbooks, a brief overview of the structure of the curriculum for Physical Sciences as laid down in the NCS Physical Sciences: Content Document (DoE, 2006) is necessary (see Appendix A). This document has guided the textbook writers and forms the content framework of each of the three books.

The Physical Sciences Curriculum Statement: Content Document covers both the Physics and Chemistry components and for this readability investigation, the structure of the Chemistry component needs to be explained in greater depth.

The Chemistry component is divided into three broad Knowledge Areas (KAs) namely: Matter and Materials, Chemical Change and Chemical Systems.

The first of these, 'Matter and Materials', is described as being an "integrated KA" (DoE, 2006:14) as it attempts to bridge the divide between the physics content and chemistry content of the curriculum and integrate the two. All aspects of atomic and molecular structure of materials are introduced in 'Matter and Materials' as well as the relationship between atomic and molecular characteristics. In this KA the 'static properties' of substances and materials are referred to, in other words, all properties other than those relating to chemical reactions.

The second KA 'Chemical Change' deals with the physical and chemical changes occurring during chemical reactions. Basic quantitative measurements and symbolic representation of these reactions are introduced. The crucial distinction between physical and chemical change is a 'principal feature' of this KA and the molecular understanding of this distinction as well as the use of balanced chemical equations, provide an opportunity to develop the ability to work with the three levels of chemical description: micro-, macro- and symbolic. The NCS Physical Sciences Content Document takes cognisance of the cognitive challenge as students attempt to integrate the three levels of description and adds that this is traditionally seen as difficult as 'the macro-, micro- and symbolic are fused into one big problem-solving nightmare.' (DoE, 2006:14) However, the Content Document argues for its inclusion by suggesting that 'giving consistent attention to this trio of descriptions right from the start of grade 10' should help students overcome the difficulties because 'the more practice one gets the easier it becomes!' (DoE, 2006:14).

The third KA, Chemical Systems, is referred to in the Content Document as a "new invention [that] aims to take chemistry out of the test tube and the school classroom and to provide a

chance to taste a bit of the real action” (DoE, 2006:14). The Global Cycles namely the water and nitrogen cycles as well as the chemistry of the hydrosphere form the content of this section.

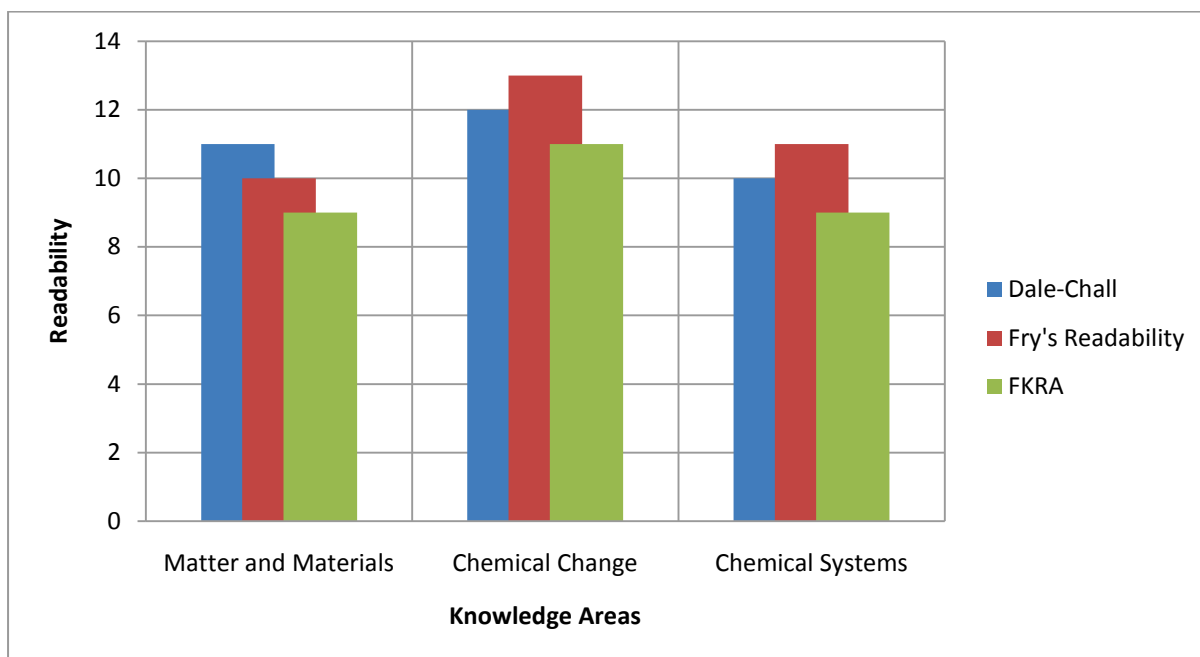
Each of the textbooks uses the divisions and KAs described above to structure the layout of the chemistry content (see Appendix B for the content pages of each of the three textbooks). The quantitative data gathering included all three of the KAs but as discussed in the qualitative data gathering (see Chapter 3, section 3.3.2. and section 3.3.3.), only the first KA was sampled qualitatively.

4.1. CASE STUDY 1: PHYSICAL SCIENCES FOR GRADE 10 2ND EDITION
(THE STUDY & MASTER SERIES)

4.1.1. QUANTITATIVE DATA ANALYSIS

The three quantitative readability measures discussed in Chapter 3, section 3.4 were applied and the readability of each of the KAs in the text was calculated as well as the average readability of the three KAs. This allowed for a deeper insight into the readability of the book. The graphs below are drawn from the tabulated results of the sampling for the textbook as illustrated in Appendix B.

Graph 1: Comparison of the readability of the Knowledge Areas of the Chemistry component using different readability formulae
(Study and Master Physical Science, Grade 10)



Graph 2: Comparison of the measures of central tendency of the three readability formulae

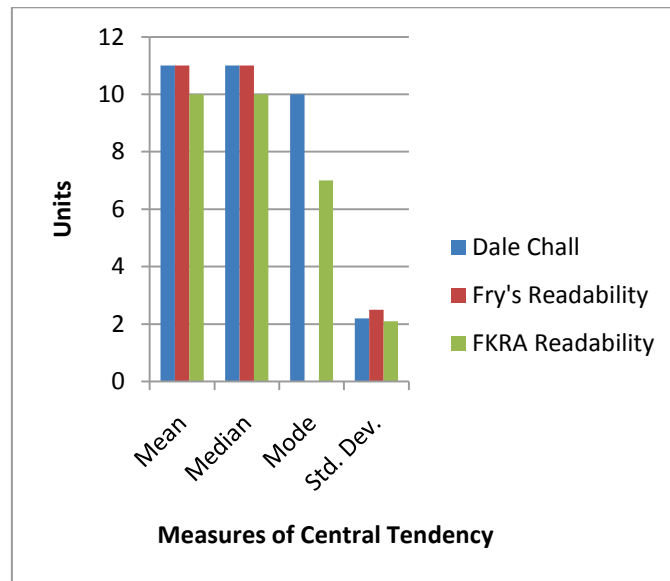


Table 1: Comparison of the measures of central tendency between the three formulae

	Dale-Chall	Fry Readability	FKRF
Mean	11	11	10
Median	11	11	10
Mode	10	multiple modes	7
Std. Deviation (SD)	2.2	2.5	2.0
Range	7	7	7

Discussion of the quantitative data depicted in the graphs and tables:

The data sets of the Dale-Chall Readability, Fry Readability and Flesch-Kincaid Readability Formula are symmetrical; their mean and median are equal.

The reading grade level of the textbook can subsequently be read off as:

- Dale-Chall reading grade level 11
- Fry reading grade level 11
- Flesch reading grade level 10

It is of interest to the study to note that the KA, Chemical and Physical Change, shows an elevated reading level consistent in each of the three formulae.

- Dale-Chall at grade level 12
- Fry Readability at grade level 13 (college level)
- Flesch-Kincaid at grade level 11

This section of the chemistry content is also cognitively challenging.

Core knowledge concepts for this section (as laid down in the NCS Content Document DoE, 2006) include:

- microscopic interpretation of macroscopic changes
- separation of particles in decomposition and synthesis reactions
- conservation of atoms and mass
- volume relationships in gaseous reactions
- balanced chemical equations

The correlation between the Dale-Chall Readability and the Flesch-Kincaid Readability Formula is .97. The Fry Readability Graph is read using a slightly different sampling method but the standard deviation of 2.5 indicates a close correlation with both the Dale-Chall Readability (SD 2.2) and the Flesch-Kincaid Readability Formula (SD 2.0).

4.1.2. QUALITATIVE DATA ANALYSIS

Two samples of the textbook were used to qualitatively investigate the cognitive-structural features of the book (see Chapter 3, section 3.3.3. on the sample selection). The samples were taken from the first chapter of the first KA: Matter and Materials.

The qualitative data analysis is sub-divided into the following six sections:

- Vocabulary used in the sampled text
- Graphicacy found in the sampled text
- Rhetorical structure of the sampled text
- Prior Knowledge Activation by the sampled text
- Level of Conceptual Difficulty of the sampled text
- Alignment of the sample of the textbook to the specific section of the Physical Science Content Document (DoE, 2006) guiding its structure

4.1.2.1. ANALYSIS OF VOCABULARY USED IN THE SAMPLED TEXTS

As noted in the review of literature (see Chapter 2, section 2.3), vocabulary is the aspect of reading that students readily identify as being the most difficult (Campbell, 1987:123) and indeed, according to Wellington and Osborne (2001:9), many of the words in science are complete strangers to students and often, a student can answer questions in science without truly comprehending the words being used.

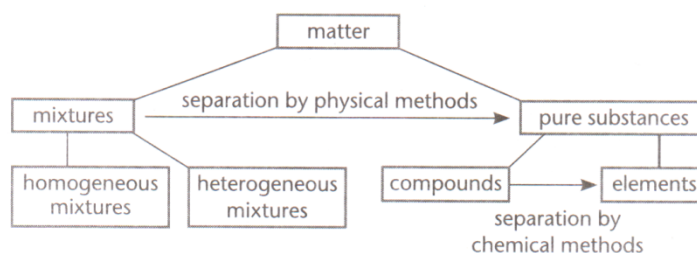
A comprehensive analysis of the vocabulary found in the two samples of the textbook, *Study & Master Physical Sciences, Grade 10* (2006) now follows.

Matter

All objects around us are made of materials. Objects have specific functions, and we choose the materials for the objects to suit these functions. Each type of material has its own unique set of properties that are determined by its microscopic composition. The properties include strength, thermal and electrical conductivity, whether it is magnetic or not, waterproof or not, and whether it is brittle, malleable or ductile. Materials consist of matter. Matter can be regarded as anything that occupies space and possesses mass. Everything around us consists of matter. **Chemistry** is the science that studies matter and the changes it undergoes.

A **substance** is a form of matter that has a constant composition, as well as distinct properties. Water, sugar, table salt, silver and oxygen are all examples of substances. Substances differ from one another in composition and can be identified by their appearance, smell, taste and other properties.

Substances can be classified into three different types: elements, compounds and mixtures. In the next few pages we will look at the properties of each of these groups.



Analysis and discussion of vocabulary usage in the sample:

The eight sentence paragraph has a high density of scientific vocabulary and words related to science. In Box 1 (below), the words have been classified according to Wellington and Osborne's taxonomy of scientific words (see Chapter 2, section 2.3.1.) and a significant number of the words fall into Level 3, the level of theoretical concepts. Wellington and Osborne (2001) draw an analogy between this level and that of Piaget's formal-operational stage of cognitive development, and they recommend that vocabulary at this level be well supported in the text. However, the words are not supported in that:

- The book does not have a glossary (see Chapter 2, section 2.3.5.).
- There are no word boxes clarifying meanings (see Chapter 2, section 2.3.5.)
- Unfamiliar words are not supported with their meanings appearing in brackets.
- The words will be unfamiliar to the novice science student as the paragraph under study is the first paragraph in the Chemistry component of the textbook (see Appendix B).

<p>Level 1: Naming Words</p> <p>1.1 Familiar objects, new names</p> <p>1.2 New objects, new names</p> <p>1.3 Names of chemical elements</p> <p>1.4 Other nomenclature</p>	<p>1.1</p> <p>1.2 oxygen</p> <p>1.3</p> <p>1.4 materials,</p>
<p>Level 2: Process Words</p> <p>2.1. Ostensive Definition</p> <p>2.2. No ostensive definition</p>	<p>2.1 microscopic</p> <p>2.2</p>
<p>Level 3: Concept words</p> <p>3.1 Sensory Concepts</p> <p>3.2 Having dual meaning</p> <p>3.3 Theoretical Concepts</p>	<p>3.1. strength, thermal, malleable, magnetic, ductile</p> <p>3.2. properties, composition</p> <p>3.3 electrical conductivity, matter, mass,</p>

Box 1. Wellington and Osborne’s Taxonomy of Scientific Words

Merzyn (1987) (see Chapter 2, section 2.3.1.), likens the science lesson to a ‘foreign language’ lesson and recommends that new vocabulary be introduced with consideration of the young science student. Little attempt has been made to support the learner in the veritable ‘flood’ of vocabulary in this first paragraph.

Furthermore four of the words: ‘materials’, ‘functions’, ‘properties’ and ‘composition’; are words that have dual meanings. Johnstone and Selepeng (2001) (see Chapter 2, section

2.2.5.3.1.), note that these words are particularly problematic if not supported properly, as the duality of meaning creates the potential for alternate frameworks, making it impossible for the reader to store the word/concept effectively.

Two non-technical words 'composition' and 'classified' are found in the sample. These words have been identified as 'troublesome' non-technical words in science (Cassels & Johnstone, 1984; Ali & Ismail, 2006). In this study, the comprehension of both words was sampled (see section 4.4., below), and only 47% of a group of learners (Xhosa-speaking chemistry students) understood the word 'composition', while 60% understood the word 'classify'. Among the sampled first language English learners, the comprehension of both words was good (see section 4.4. below).

Everyday or high frequency words have been replaced with less common synonyms e.g.

- 1.3 'occupies'... instead of... 'takes up'
- 1.4 'possesses'... instead of... 'has'
- 1.5 'can be regarded as'... instead of... 'is'

Referent terms are used interchangeably with 'objects', 'materials', 'matter' and then 'substances' all meaning the same thing.

The use of terms such as 'to suit', 'regarded as' and 'identified by' is what Barnes (1973) calls the 'language of secondary education' and he suggests that it be avoided, as far as is possible, and that language be brief and concise (see Chapter 2, section 2.3.1.).

The word 'properties' is continually given a classification. For the purposes of this analysis the classification of the word is in bold and appears as:

- **unique set of** properties;
- **distinct** properties;
- **other** properties; and
- **the** properties.

This classification of the concept 'properties', before its conceptual meaning is firmly established, will be a source of confusion to the reader leading to misconception of the concept (see Chapter 2, section 2.2.5.3.1.).

The sample is full of nominalization (see Chapter 2, section 2.3.6.), with science 'stated' as a product, *fait accompli*, and clinically presented, thus keeping the reader at a distance. One example of this is found in the clause "determined by its microscopic composition", the nominalization of the verb 'compose', forming the noun 'composition', and then further compounding the difficulty by adding the classification of 'microscopic' to the word 'composition'.

'Matter' (a scientific concept) is shown to 'possess' and 'occupy'. Furthermore, matter is said to be 'regarded as' but no indication is given as by whom matter is so regarded; human activity is kept from the picture. This fact is presented as being universal and unquestionable, in other words 'Matter is regarded by all as being anything that occupies space and possesses mass'.

4.1.2.1.2. SAMPLE 2 taken from Study & Master Physical Sciences Grade 10, 2nd edn.,
2006:153

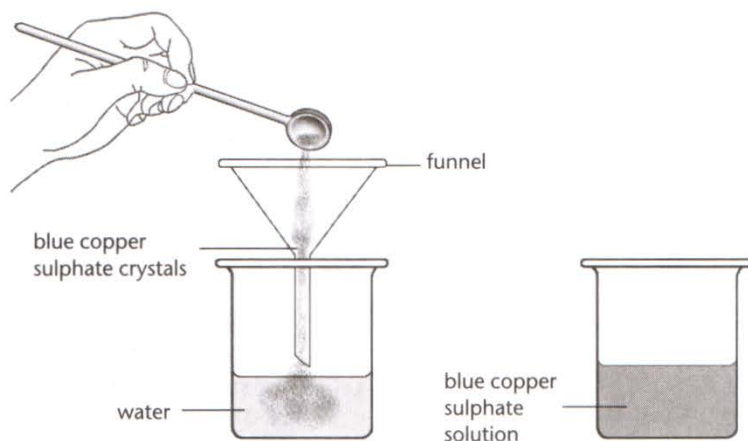
(SAMPLE IS ON THE FOLLOWING PAGE - PAGE 98)

Mixtures

We seldom come into contact with pure substances in everyday life. The air we breathe, the water in the rivers, lakes and oceans, and also Earth itself, are all composed of mixtures of substances. A mixture is a combination of two or more substances in which the substances retain their own properties. A mixture's composition does not remain constant. If one were to collect air samples in Cape Town, Johannesburg and Pietermaritzburg, they would differ in composition because of differences in altitude, pollution, and so on. Mixtures are either homogeneous or heterogeneous.

Homogeneous mixtures

When a spoonful of salt dissolves in a beaker of water we get a **homogeneous mixture** in which the composition of the mixture is the same throughout. A homogeneous mixture is also called a **solution**. In solutions we distinguish between the **solute** and the **solvent**. The component that represents the largest amount is called the solvent. The solute is the substance that dissolves in the solvent. In a salt solution, the water is the solvent and the salt is the solute. Substances that dissolve in water are **soluble** in water. Let us now look at a few examples of solutions.



Gaseous solutions

Gases always mix completely with each other. Air consists of 78,0% nitrogen, 20,9% oxygen, 0,9% argon, and traces of carbon dioxide and other gases. Natural gas consists of methane and ethane with small amounts of propane.

Liquid solutions

Tincture of iodine is a solution of solid iodine crystals dissolved in alcohol. Rubbing alcohol consists of 70% 2-propanol and 30% water. Alcoholic drinks are solutions of varying amounts of alcohol and

other chemicals, such as colourants, flavourants and preservatives in water. Wine contains about 12% ethanol, and beer about 5% ethanol. All fizzy drinks contain carbon dioxide gas dissolved in the liquid cooldrink.

Solid solutions

Almost all metal alloys are really solutions of one solid dissolved in another solid. Brass contains about 70% copper and 30% zinc, bronze consists of copper and tin in varying proportions, and carbon steel has 1,0% manganese and 0,9% carbon in iron.

Heterogeneous mixtures

If sand is mixed with iron filings, the sand grains and the iron filings

Analysis and discussion of the vocabulary usage in the sample:

Box 2 (below) classifies the words according to Wellington and Osborne's taxonomy and it is evident that the vocabulary is challenging to the science learner.

<p>Level 1: Naming Words</p> <p>1.1 Familiar objects, new names</p> <p>1.1 New objects, new names</p> <p>1.3 Names of chemical elements</p> <p>1.4 Other nomenclature</p>	<p>1.1</p> <p>1.2 tincture of iodine, rubbing alcohol, brass, metal alloys, bronze,</p> <p>1.3 carbon dioxide, argon, oxygen, nitrogen, zinc, copper, tin, manganese</p> <p>1.4 methane, ethane, propane, 2-propanol, ethanol, carbon steel, alcohol, carbon in iron</p>
<p>Level 2: Process Words</p> <p>2.1 Ostensive Definition</p> <p>2.2 No ostensive definition</p>	<p>2.1 dissolve</p> <p>2.2</p>
<p>Level 3: Concept words</p> <p>3.1 Sensory Concepts</p> <p>3.2 Having dual meaning</p> <p>3.3 Theoretical Concepts</p>	<p>3.1 homogeneous mixture, heterogeneous mixture</p> <p>3.2 substances</p> <p>3.3 solute, solvent, solution, component,</p>

Box 2. Wellington and Osborne's Taxonomy of Scientific Words

The naming words in this instance are particularly problematic, if not supported by a glossary. For example, 'tincture of iodine' will likely have no link to a learner's background knowledge; 'carbon in iron' is in effect describing a process whereby iron is given a measure of flexibility by the addition of carbon granules; and 'rubbing alcohol' will also be foreign to most learners in a grade 10 class. Linking new concepts to the reader's background knowledge makes the texts accessible (see Chapter 2, section 2.2.1.2.).

The nomenclature used: 'methane', 'ethane', 'propane', 'ethanol' and '2-propanol' are organic compounds that will be completely unfamiliar to most learners in grade 10 and can hardly be pointed to, or 'shown' in many of South African school laboratories or science

classes. Organic chemistry is a component of chemistry that is studied in grade 12. Wellington and Osborne (2001) (see Chapter 2, section 2.3.1.) caution the writers of scientific material to take the Piagetian stage of the reader into account and Johnstone (see Chapter 2, section 2.2.5.3.1.) stresses the difficulties encountered when a reader experiences cognitive overload.

To the immature, developing reader (particularly the ESL reader) a 'homogeneous mixture' is likely to be understood as a salt mixture. The definition that the writer intended is that a homogeneous mixture is one in which the composition is the same throughout. However, this definition is stated implicitly, and directly after this implicit definition, a 'homogeneous mixture' is then given an alternate name: "is also called a solution". This will further confuse the reader.

The non-technical word 'composition' is used in various forms throughout the paragraphs.

The 'language of secondary education' (Barnes, 1973) abounds, for example:

- 'distinguish between'
- 'retain their'
- 'if one were to'

Nominalization is also present in the dehumanizing of the processes described and science is presented as a list of unquestionable facts. The reader is separated in this way from the text and this 'un-involvement' raises the readability (see Chapter 2, section 2.3.6.).

4.1.2.2. ANALYSIS OF THE GRAPHICACY FOUND IN THE SAMPLED TEXTS

Langhan (1990) cites Smith and van Rooyen (1990:87) who report that visuals accompanying text have three main functions:

- The visual medium together with language is intended to provide meaning for the reader of an unfamiliar language.
- By combining visuals and language, learning is reinforced and is optimal.
- Visuals generally get attention and encourage the reader to delve deeper and to find out more.

In the data analysis of the graphicacy that follows, each sample is viewed through a lens created by these three functions.

4.1.2.2.1. SAMPLE 1 taken from Study & Master Physical Sciences Grade 10, 2nd edn., 2006:124

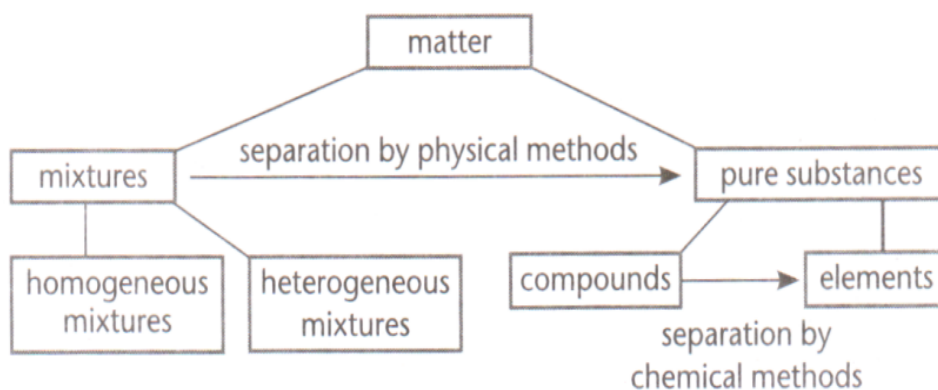


Figure 1 Graphicacy Sample 1 (S&M 2006:124)

Analysis and discussion of the graphic:

The flowchart included after the paragraphs, has no title or caption.

The words/phrases: ‘heterogeneous’, ‘homogeneous’, and ‘pure substances’ appear in the flowchart yet are not found in the preceding text. This is also true of ‘separation by physical methods’ and ‘separation by chemical methods’ where the words form labels in the graphic but are not supported in the preceding text.

The flowchart hampers the overall readability of the passage as it is not referred to in the text, neither does it support the text in a meaningful way. Mayer (1989) (see Chapter 2, section 2.2.4.) notes that diagrams need to be supported by the text and are meaningful to the reader in so far as they have this support. The reader should not have to read the diagram in isolation from the text. Visual support for the text to aid comprehensibility is particularly important for students studying science in a language not their own (see Chapter 2, section 2.2.4.).

4.1.2.2.2. SAMPLE 2 taken from Study & Master Physical Sciences Grade 10, 2nd edn.,
2006:153

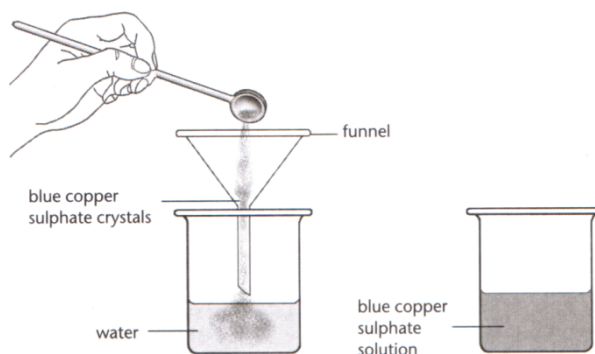


Figure 2 Graphicacy Sample 2 (S&M 2006:125)

Analysis and discussion of the graphic:

The graphic, although having labels, has no caption or title. It is not referred to in the text and the labels: 'blue copper sulphate crystals' and 'blue copper sulphate solution' do not appear in the text above or in the text which follows it.

The picture of the beakers and solutions is placed at the end of a paragraph that concludes: "Let us now look at a few examples of solutions". The reader is signaled to link the instruction of "let us look at a few examples of solutions" with the diagram following. However, there is no link between the text and the diagram, nor the instruction and the diagram. The first example then referred to in the text is headed: 'Gaseous Solutions'; this is then followed by 'Liquid Solutions' and then 'Solid Solutions'. In none of these, is copper sulphate or a solution thereof referred to. Langhan notes (1990) (see Chapter 2, section 2.2.1.1.) that misleading signaling is a severe cause of readability impairment, especially for an ESL reader.

4.1.2.2.3. GENERAL EXAMPLES OF GRAPHICACY FROM MATTER AND MATERIALS




Four further examples of graphicacy from the KA 'Matter and Materials' are now briefly examined.

1. Figure 3 (below) comprises three pictures, the caption of which is "Separating iron and sulphur". However, as neither the iron nor the sulphur is labeled in the picture, the reader must infer from the caption, that the iron is that which is clinging to the magnet.



Figure 3 Graphicacy Sample 3 (S&M, 2006:129)

2. Figure 4 (below) is a poor example of tabularization, which makes the table difficult to read. The rows are not labeled; they should be labeled as: composition, properties, separation methods, diagrammatic representation. The pictorial representation of elements, compounds and mixtures (see the last row of the table), is stressed in the NCS Physical Sciences Curriculum: Content Document (DoE, 2006) as important in aiding students to link macroscopic and microscopic concepts. However, the pictorial representation appears for the first time in this table and the pictures have not been explained to the reader. The reader will be confused as to the purpose and meaning pictures of the little black 'baubles' and 'open dots' pictures found in the last row.

Element	Compound	Mixture
Consists of one kind of atom	Composition is constant	Composition can vary and consists of two or more elements or compounds
Properties are unique	Properties differ from those of the constituent elements	Properties are the same as those of the constituent substances
Cannot be separated by chemical or physical methods	Can be separated by chemical methods	Can be separated by physical methods
		

Elements

Figure 4 Graphicacy sample 4 (S&M, 2008:130)

3. In Figure 5, the Periodic Table of Elements is introduced for the first time with graphics that are likely to confuse the reader. The purpose of the Roman Numerals at the tops of columns is not explained, and the numbers above each symbol have not been explained; they are therefore likely to be meaningless to the reader. In chemistry texts, the Periodic Table of Elements is an important document and often there is the need to refer to parts of it or represent it in part. When this is the case, a reference to the comprehensive Period Table will normally be given. However, in the sample below, no reference is made to a clearer table or to a list of the symbols of the elements and their corresponding names.

I																		to non-metallic.										VIII									
1 H																		2 He																			
3 Li	4 Be															5 B	6 C	7 N	8 O	9 F	10 Ne																
11 Na	12 Mg															13 Al	14 Si	15 P	16 S	17 Cl	18 Ar																
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr																				
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe																				
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn																				
87 Fr	88 Ra	89 Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub																										
																		58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu						
																		90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr						

metals
metalloids
non-metals

Metals

Figure 5 Graphicacy sample 5 (S&M, 2008:133)

4.1.2.3. ANALYSIS OF THE RHETORICAL STRUCTURE FOUND IN THE SAMPLES

As reviewed in the literature (see Chapter 2, section 2.2.1.) for any reader, text can only be processed and comprehended meaningfully once placed in an overall framework or schema (Anderson, Pichert & Shirey, 1983; Lorch & Puzles Lorch, 1985; Armbruster,1986). The schema enables the reader to situate the major themes, secondary themes, and supporting details in relation to one another in such a way that comprehension and recall are facilitated.

In her discussion of the 'Role of the Author' in writing texts for scholars, Armbruster (1984) recognizes the responsibility of the author in producing well structured texts. Sharp (1999) (see Chapter 2, section 2.2.1.1.) specifically refers to signaling, the strategic placing of the topic sentence and clarity of logical relationships that the authors use for text structures and recommends that these be apparent especially in assisting the ESL reader to comprehend the text.

The above are some of the factors which will be foregrounded the analysis of the rhetorical structuring of the samples.

4.1.2.3.1. SAMPLE 1 taken from Study & Master Physical Sciences Grade 10, 2nd edn., 2006:124

The sample now analyzed and discussed is found above in section 4.1.2.1.1.

The paragraph has no particular rhetorical structure and the title '**MATTER**', gives little clue as to what is to follow in the paragraph. An explicit rhetorical structure is considerate of the novice science reader (see Chapter 2, section 2.2.1.1.). The topic sentence: "Matter can be regarded as anything that occupies space and possesses mass", stands alone towards the end of the paragraph. Langhan (1990) (see Chapter 2, section 2.2.1.1.) stresses the importance of having the topic sentence appear first in a paragraph, especially if text is to be read by ESL readers.

Furthermore the sequencing of sentences shows little 'consideration' for the reader, especially the ESL reader, as there is no signaling from one sentence to another, concepts follow rapidly one on another and implicit definitions abound. The sequencing is as follows with the topic sentence highlighted in red for the purpose of analysis :

- All objects around us are made of materials.
- Objects have specific functions and we choose the materials to suit these functions.
- Each type material has its own unique properties determined by its microscopic composition.
- The properties include strength, thermal and electrical conductivity, whether it is magnetic or not, waterproof or not, and whether it is brittle, malleable or ductile.
- Matter consists of materials.
- **Matter can be regarded as anything that occupies space and possesses mass.**
- Everything around us consists of matter.
- Chemistry is the science that studies matter and the changes it undergoes.

The reader will experience severe working memory overload as an attempt is made to link each concept to some background knowledge, hold that 'chunk' of knowledge in working memory for processing of the concept and then attempt to link the information with the following concept. WMC and the danger of cognitive overload is shown to retard readability (see Chapter 2, section 2.2.5.3.1.).

As reviewed in the literature (see Chapter 2, section 2.2.1.1.), readers comprehend a text when they are able to activate schemas that match the particular content and structure of the material. As they begin to read, readers search for schemas that elucidate the text, and using these, construct a partial and tentative model of the text's meaning. This model then serves to scaffold the continued search through the text and is progressively refined as the reader gathers more information from the text (Armbruster, 1986). Comprehension is thus dependent on the progressive refinement of a coherent model of the text's meaning by the reader. As the sample above (Sample 1) is read, the reader will try to construct a model of

the text's meaning but the lack of rhetorical structuring will make this task difficult, severely compromising comprehension and impairing readability.

4.1.2.3.2. SAMPLE 2 taken from Study & Master Physical Sciences Grade 10, 2nd edn.,
2006:153

This sample now analyzed and discussed is to be found in section 4.1.2.1.2.

An analysis and discussion of the rhetorical structuring now follows.

The paragraph is headed by the word: 'Mixtures' which gives no clear indication of what is to follow in the paragraph.

In sentence 1 'We seldom come into contact with pure substances in everyday life', the word 'seldom' implies that we generally come into contact with "substances that are not pure". This meaning is not explicit but the reader must infer it from the text.

In sentence 2, 'The air we breathe, the water in the rivers, lakes and oceans, and also Earth itself, are all composed of mixtures of substances', the examples of mixtures are air, water and Earth. The material could be explicitly presented by a simple reorganization of the text to make it more considerate of the reader. For example: 'Examples of mixtures are the air that we...'

Sentence 3, 'A mixture is a combination of two or more substances in which the substances retain their own properties', is the topic sentence and, as in Sample 1 above, it is not found at the beginning of the paragraph. The sentence can be broken up into the following parts:

- a mixture is a combination of two or more substances
- substances have unique properties
- substances retain their properties in a mixture

The reader would have to comprehend the words 'combination' and 'retain' to make sense of the sentence. Furthermore, the sentence has two concepts embedded in

it: namely that a mixture is a combination and that the component parts retain their properties although 'mixed' together.

Sentence 4, 'A mixture's composition does not remain constant' is conceptually challenging as a number of theoretical concepts have been rapidly introduced and linked together in the foregoing three sentences and now a fourth component is added, that of a mixture's composition not being static.

Sentence 5, 'If one were to collect air samples in Cape Town, Johannesburg and Pietermaritzburg, they would differ in composition because of the differences in altitude, pollution, and so on' holds implicit information that the reader must infer. The implication is that even "mixtures" that would appear to be the same, for example air samples, are different because the properties of their component parts are different at differing altitudes, as a consequence of differing air pollution additives etc.

By describing mixtures as being either homogeneous or heterogeneous; (sentence 6), for the reader, mixtures are now either air, Earth or water. He/she would not understand the implicit meaning that mixtures 'fall into two broad categories' namely 'homogeneous mixtures' and 'heterogeneous mixtures' of which air, Earth and water are examples.

-

As is clear from the above sentence-by-sentence analysis, the paragraph has no particular rhetorical structure and this will confuse even an expert reader. The following is evident from the analysis:

- Background knowledge is not activated in a meaningful way.
- The text is inconsiderate of the reader and even more so of a reader reading in a language not their own by having no rhetorical structure.
- Definitions of concepts are all implicitly presented.
- The vocabulary is not supported.

A further example of a confusing rhetorical schema is found in the paragraph headed 'Pure substances'. The paragraph begins with: 'To understand the difference between mixtures and pure substances we have to understand how mixtures and compounds form'. The signaling in the heading is to 'pure substance' and then the reader is led into the differences between mixtures and pure substances.

4.1.2.3.3. USE OF HIGHLIGHTED WORDS FOR EMPHASIS

In both Sample 1 and Sample 2, analyzed under sections 4.1.2.1., 4.1.2.2. and 4.1.2.3., words are highlighted in bold with no specific order or recognizable pattern. Sometimes it is the heading of the paragraph that is highlighted in the text that follows but this is done at random.

- Sample 1 (S&M, 2008:124)

The sample has three paragraphs and a single heading 'Matter'. Two words are highlighted in the three paragraphs, namely: 'Chemistry' and 'substance'.

- Sample 2 (S&M, 2008:125)

The heading of the sample is 'Homogeneous mixtures' and four words are highlighted: 'homogeneous mixture', 'solute', 'solution', 'solvent' and 'soluble'.

The emphasis implied by the highlighted words is very obscure and of little help in giving support to the reader. On the contrary, the unexplained emphasis will likely cause confusion and raise the readability level of the text.


4.1.2.3.4. USE OF WORD BOXES TO CLARIFY AND AUGMENT THE TEXT

Word boxes captioned "Did you know?" are a feature of the book. At the beginning of the book, when instructions are given to readers on how to use them, they are directed to the "Did you know?" boxes with the commentary that these provide 'interesting additional information' that will help them, as readers, relate the concepts that they are learning about to real life situations. All the samples now analysed are copied directly from the text.


- The “Did you know?” box (as depicted below) contains distracting information on what symbols the alchemists in medieval times used to name elements. This serves to support the ‘seductive detail effect’ (see Chapter 2, section 2.2.3.), in that interesting but irrelevant information is introduced into the main body of the text, that is likely to confuse Grade 10 readers, as they do not have a firm comprehension of the symbols and names of chemical elements.

DID YOU KNOW?


The alchemists in medieval times used symbols like these to name elements.



Sulphur (S)



Silver (Ag)



Copper (Cu)

The symbols of most elements in the modern Periodic Table are derived from their Latin or Greek names, but some of them come from their English names.

Symbol	English name	Latin name
Ag	Silver	<i>Argentum</i>
Au	Gold	<i>Aurum</i>
Cu	Copper	<i>Cuprum</i>
Fe	Iron	<i>Ferrum</i>
Na	Sodium	<i>Natrium</i>
Pb	Lead	<i>Plumbum</i>
Sb	Antimony	<i>Stibium</i>

Compounds

Most elements can interact with one or more other elements to form compounds. Hydrogen gas, for example, burns in oxygen gas to form water, which has properties that are distinctly different from those of the materials we started with. Water is made up of two parts

- “Did you know?” box (as depicted below), gives the first indication of the grouping used in the Periodic Table of Elements. This grouping is referred to and necessary for comprehension in the next unit of the book. The box also contains an excess of information that is likely to cause the reader to experience a cognitive overload.

DID YOU KNOW?

Group I metals

These metals include **lithium, sodium** and **potassium**. They are very reactive and always occur as compounds.



The compound with which we are very familiar is table salt (*sodium chloride*).

Caustic soda (*sodium hydroxide*) is used in oven and drain cleaners; soda ash and washing soda (*sodium carbonate*) are used for making glass, soaps, detergents, medicines and food additives.

Baking soda, also called bicarbonate of soda (*sodium hydrogen carbonate*), is used in medicines for neutralising stomach acids and also in baking powder.



Potassium ions are essential for plant growth, and all living matter needs sodium and potassium ions in their body fluids.

Chile saltpetre (*sodium nitrate*) is used in gunpowder and other explosives.

Potash (*potassium carbonate*) is found in the ashes of burned plants and wood.

Lithium carbonate is used in drugs to treat manic depression.

Group II metals

These metals include **beryllium, magnesium, calcium** and **barium**.

Magnesium and *calcium* ions, together with sodium and potassium ions, make up a large part of the soluble ions in sea water.

Calcium is an essential part of our bodies, as it is the major component of bones and teeth.



Sea animals use *calcium ions* and combine it with carbonate ions to create their shells.



Milk of magnesia is an antacid and laxative and is a suspension of *magnesium hydroxide* in water.

Gypsum (*calcium sulphate*) is also called plaster of paris and was used to mould casts for broken limbs.

Dolomite (*calcium magnesium carbonate*) and limestone (*calcium carbonate*) are responsible for the beautiful stalactites and stalagmites in the Congo Caves and Sodwana Caves.

Emerald and aquamarine are beautiful green gemstones that contain *beryllium*.

We use Epsom salts (*magnesium sulphate*) as a laxative, but also in fertilisers and in the dyeing and tanning industries.

Quicklime (*calcium oxide*) is an important ingredient in Portland cement. When it is mixed with water, it forms slaked lime (*calcium hydroxide*).

When *barium sulphate* is ingested, it can be seen clearly on an X-ray photograph. Doctors use this substance to help them examine the digestive tract.

Calcium chloride can absorb water and is used in small sachets to keep powders and pills dry.

Magnesium burns brilliantly white in air and is used in flash photography and flares.



- "Did you know?" box (as depicted below) details and explains the scientific method, an important component of the scientific investigative process. This box breaks up the

text and is in the middle of a section outlining the history of the atom, bearing no relevance to the text. For it to contribute meaningfully, it needs to be placed where it can be more relevant. Furthermore, it needs to be supported by examples, as well as exercises giving the reader an opportunity to practise the method. Its current placing impairs the readability of the text and the information it contains is lost to the reader.

suggests that there are still more questions than answers. A true scientist always has an open and enquiring mind. The scientific future certainly will challenge our creativity.

DID YOU KNOW?

The **scientific method** is the systematic approach to research used by all sciences. There are 5 steps in the scientific method:

Step 1: Identify and state the problem.

Step 2: Do experiments; collect data; make careful observations.

Step 3: Analyse the data and propose a possible solution to the problem by formulating a hypothesis.

Step 4: Do more experiments to test the hypothesis. Make sure the conclusions are correct.

Step 5: Formulate the results as a conclusion. The conclusion can be in the form of a theory or a law.

- A hypothesis is a tentative explanation of the results of experiments or of a set of observations.
- A theory is a hypothesis that has withstood extensive testing.
- A law is a verbal or mathematical description of behaviour based on the results of many experiments. Laws are consistent and have no known exceptions.
- A model is a real or mental picture that results from ideas and assumptions that are imagined to be true. It is used to explain certain observations and measurements.

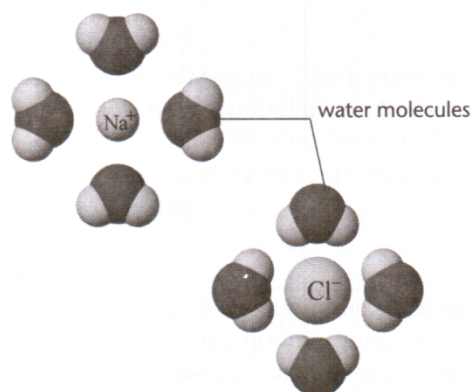
The structure of the atom

Atoms consist of three main particles: **protons (p^+)**, **neutrons (n^0)** and **electrons (e^-)**. The nucleus of an atom lies at its centre and contains protons and neutrons, collectively called the **nucleons**.

4.1.2.4. DECREASING COGNITIVE LOAD AND THE MANNER IN WHICH MULTI-LEVEL LEARNING ASPECTS AND SYMBOLIC LANGUAGE IS PRESENTED

A further sample from the third KA of the chemistry curriculum: 'Chemical Systems', is now briefly examined. The samples are copied directly from the text so that a general overview of the paragraphing and density of the writing can be seen.

4.1.2.4.1. Sample 3 taken from Study & Master Physical Sciences Grade 10, 2nd edn., 2006:264

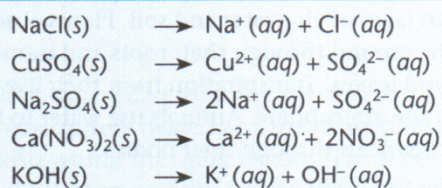


When an ionic substance, such as sodium chloride, is stirred into a beaker of water, the water molecules are attracted to the positive sodium ions and the negative chloride ions. New forces, called **ion-dipole forces**, between the water dipoles and the ions replace the electrostatic forces in the solid sodium chloride. The water molecules separate the sodium ions and chloride ions, and the salt dissolves in the water.

The words 'electrostatic forces', 'dissociate' and 'ion-dipole' in Sample 3 above are conceptually abstract and would need careful scaffolding. This support is absent.

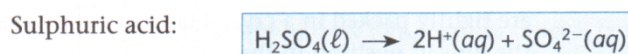
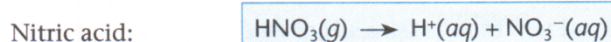
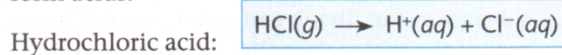
4.1.2.4.2. Sample 4 taken from Study & Master Physical Sciences Grade 10, 2nd edn., 2006:264

When ionic salts dissolve in water, their ions *dissociate* from each other. The same happens with alkalis in solution. The dissociation of some of these ionic salts and soluble bases are written as follows:



Ionisation is a chemical process. Dissociation is a physical process.

Certain covalent molecules can *ionise* when they dissolve in water to form acids.



Symbolic language falls into the 4th level of Wellington and Osborne's taxonomy (2001) and the reader needs to go through approximately seven cognitive steps to understand just one of the chemical equations below (see Chapter 2, section 2.3.4).

There is far deeper coverage of content than curriculum content document prescribes, leading to, it being conceptually challenging for a grade 10 level learner.

- Graphicacy again does not aid the understanding of the process being described in the accompanying text.
- The content in the paragraphs continually moves from macro to micro to symbolic concepts. The triangle described by Johnstone (2006) (see Chapter 2, section 2.2.5.3.2.) cautions the rapid movement through the macro-, micro- and symbolic, and in the above samples, the learner would need to be cognitively in the 'middle of the triangle' most of the time, to understand what is being explained.

4.1.2.5. ALIGNMENT OF THE TEXTBOOK TO THE CURRICULUM

Textbooks are not written in isolation but are guided by a national curriculum (See Chapter 2, section 2.4.4.) and these need to be aligned with the specific subject content prescribed by curriculum documents. The defect of note for the purposes of this study on readability is that unsuitable textbooks will be produced if their elaboration is not coordinated with that of curricula.

In this section of the qualitative data analysis, the prescribed content of the curriculum document is given for each of the samples and then the samples are analysed to ascertain how closely they match the curriculum.

As has been reviewed in Chapter 2 (see section 2.4.5.), the Curriculum Guidelines for the changes implemented in 2005/2006 have been criticized as being inadequate and opaque. A brief description of the NCS Physical Sciences Curriculum: Content Document (DoE, 2006) (see Appendix) is follows and then the analysis.

The NCS Physical Sciences: Content Document (see Appendix A) has four columns and an explanation is given in the document of the four. This is as follows (DoE, 2006:3):

- The first column of the core knowledge and concepts section is an extract from the National Curriculum Statement for FET General (Physical Sciences).
- The second column gives depth to the concepts appearing in the first column.
- The third column also gives depth to the concepts but these concepts will be examined when the curriculum is fully implemented after 2010.
- The last column contains commentary, advice and links on how to teach the concepts. The tips in this column are very useful as they give the teacher insight into how ‘to teach’ and sometimes how ‘not to teach’ the concepts. It also gives guidance on the misconceptions that are inherent in some of these topics.

DoE document (2006:35) (see Appendix A):

- Describe an homogeneous mixture as a mixture with component parts that are indistinguishable from each other, like all in the same phase (the atmosphere is a mixture of oxygen, nitrogen, argon,...) or salt water.
- Give examples of common mixtures.

An excerpt from Sample 2 taken from Study & Master Physical Sciences Grade 10, 2nd edn., 2006:153.

“When a spoonful of salt dissolves in a beaker of water we get a homogeneous mixture...A homogeneous mixture is also called a solution. In solutions we distinguish between the solute and the solvent. The component that represents the largest amount is called the solvent. The solute is the substance that dissolves in the solvent [] substances that dissolve in water are soluble in water.

Gaseous solutions described as: air consists of 78.0% nitrogen, 20.9% oxygen, 0.9% argon, and traces of carbon dioxide and other gases. Natural gas consists of methane, ethane with small amounts of propane

Liquid solutions described as: Tincture of iodine...Rubbing alcohol...Wine contains about 12% ethanol, and beer about 5% ethanol

Solid solutions described as: Metal alloys; brass contains about 70% copper and 30% zinc, bronze consists of copper and tin in varying proportions, and carbon steel has 1,0% manganese and 0,9% carbon is iron.”

Analysis and discussion of the interpretation of the DoE Document (2006) by the author as reflected in the above excerpt from the textbook:

The textbook gives detailed, in-depth definition of a homogeneous mixture with the component parts given in technical terms. These terms are used at the discretion of the author as the NCS Physical Sciences: Content Document (2006) does not specifically mention these technical terms. However, the document also leaves depth to which the content is expounded, to the textbook writers.

The NCS Physical Science: Content Document (2006) stipulates ‘common mixtures’, the author has used what is common to herself but not necessarily common to a grade 10 student.

Further discussion of the alignment of the textbook to the Content Document:

The textbook includes ‘suspensions’, ‘miscible’, ‘immiscible liquids’ and ‘emulsions’ under heterogeneous mixtures while no mention of these terms are made in the NCS Physical Sciences: Content Document. The understanding of the terms is particularly difficult for the novice scientist.

The Content Document states “given a list of key discoveries, match these to the description of the atom that followed the discovery” (DoE, 2006:42). The textbook then has a ten page, detailed interpretation of these key discoveries, the comprehension of which requires complex cognitive thinking and reasoning skills.

It is clear that the depth of content covered by the textbook is excessive and in a number of instances, content not included in the Content Document is covered in the textbook.

As Seguin (1989) notes, the alignment of the textbooks to the prescribed curriculum is important for ensuring they are effective as LTSM and the recommendations of the Review

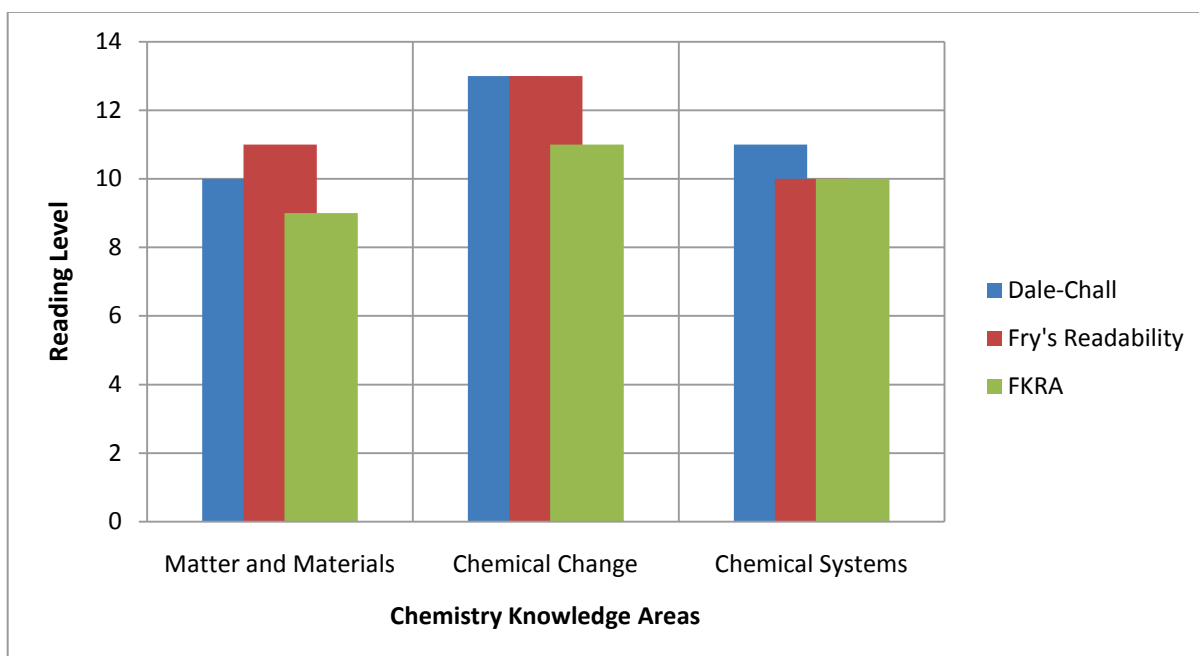
Committee (see Chapter 2, sections 2.2.5. and 2.4.4.) are clear as they argue for “the production of excellent textbooks clearly aligned to the curriculum (DoE, 2009:16) .

4.2. CASE STUDY 2 : *FOCUS ON PHYSICAL SCIENCES, Grade 10. 1st Edition (2006)*

4.2.1. QUANTITATIVE DATA ANALYSIS

As noted above in 4.1.1., the chemistry section of the grade 10 physical science content is divided into three KAs and the readability of each KA was calculated. The results are illustrated in the graphs below.

Graph 1: Comparison of the readability of the modules within the chemistry content
(Focus on Physical Sciences, Grade 10. 2006)



Graph 2: Comparison of the measures of central tendency of the three readability formulae

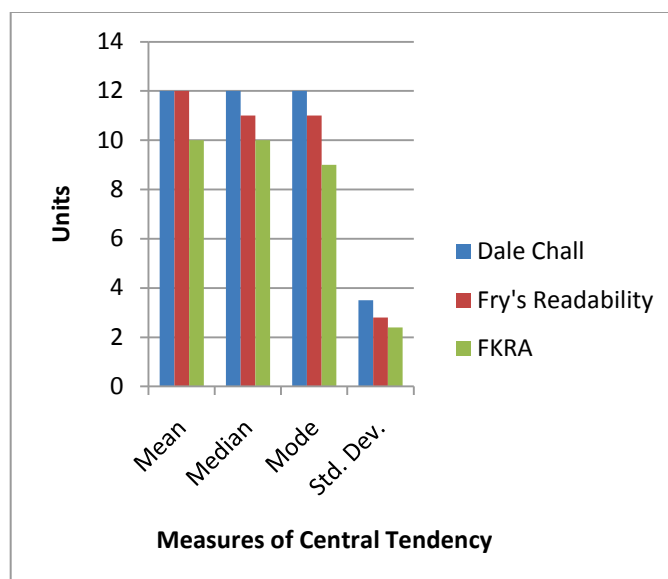


Table 1: Comparison of the measures of central tendency between the three readability formulae

	Dale-Chall	Fry	Flesch-Kincaid
Mean	12	12	10
Median	12	11	10
Mode	12	11	9
Std. Deviation	3.5	2.8	2.4

Discussion of the quantitative data depicted in the graphs and tables:

The data set of the Flesch-Kincaid Readability Index is symmetrical; the mean and median are equal. The reading level for the chemistry section of the book is then at grade level 10 (see Chapter 3, section 3.5.).

The data sets of the Dale-Chall Readability Formula and Fry Readability are slightly skewed to the left as the mean is smaller than the median. The difference is significantly small and thus the reading level for the chemistry section of the books is read off at grade level 13 and grade level 11 respectively (see Chapter 3, section 3.5).

It is to be expected that the Dale-Chall Readability formula would give a slightly higher reading level than that of Fry and Flesch-Kincaid, as the formula takes into account 'difficult words'. Chemistry vocabulary is by nature loaded with unusual and challenging words and this is reflected in the reading level registered by the formula.

It is of interest to the study to note that the section, Chemical and Physical Change, shows an elevated reading level consistent in each of the three formulae.

- Dale– Chall at grade level 13 (college level)
- Fry at grade level 13 (college level)
- Flesch-Kincaid at grade level 11

This section of the chemistry content is also cognitively challenging.

As noted previously, core knowledge concepts for this section as laid down in the NCS content document include:

- microscopic interpretation of macroscopic changes
- separation of particles in decomposition and synthesis reactions
- conservation of atoms and mass
- volume relationships in gaseous reactions
- balanced chemical equations

The correlation between Dale-Chall Readability and Flesch-Kincaid Readability is .95.

4.2.2. QUALITATIVE DATA ANALYSIS

As in the qualitative data analysis of Case Study 1, two samples of the Focus textbook were used to qualitatively investigate the cognitive-structural features of the book (see Chapter 3, section 3.3.3. on the sample selection).

The samples were taken from the beginning of the Chemistry section, thus from the first chapter of the KA: Matter and Materials. This follows the same protocol observed in Case Study 1.

The subdivision of the qualitative data analysis follows the same order as that used in Case Study 1 namely:

- Vocabulary used in the sampled text
- Graphicacy found in the sampled text
- Rhetorical structure of the sampled text
- Prior Knowledge Activation by the sampled text
- Level of Conceptual Difficulty of the sampled text
- Alignment of the sample of the textbook to the specific section of the Physical Science Content Document (DoE, 2006) guiding its structure

4.2.2.1. ANALYSIS OF VOCABULARY USED IN THE SAMPLED TEXT

As noted in the introduction to Case Study 1 (see section 4.1.2.1.), vocabulary is the aspect of reading that students readily identify as being the most difficult (Campbell, 1987:123).

A comprehensive analysis of the vocabulary found in the two samples of the textbook, Focus on Physical Sciences, Grade 10. 1st edn. (2008), now follows.

4.2.2.1.1. SAMPLE 1 taken from Focus on Physical Sciences, Grade 10. 1st edn., 2008: 120

(SAMPLE IS ON THE FOLLOWING PAGE – PAGE 122)

1. Composition, properties and uses of materials

In your earlier studies in the Natural Sciences, you learnt that matter is anything that has mass and occupies space, and that matter can occur in three states or phases: solid, liquid and gas.

Materials are substances that are made from matter. Everything you see around you is made up of some type of material. This chapter explores the macroscopic **properties** of materials. You will learn about the different ways of observing, describing and classifying materials. We will look at what materials are **composed of** (their composition) and their **properties**. We will also link the uses of materials with their properties.

1.1 What are materials composed of?

Objects around us are made from various materials. Some materials are natural (like cotton and wool), while others are man-made (like plastic). Man-made materials can be completely artificial, that is, made by man from scratch, whereas others are made by man's processing of natural resources.

Activity 1 Comparing materials used in ancient times with those used today (pairs)

LO2 AS3

Look at Figure 4.1. Have a discussion on the differences between the two groups of people and what you notice in the pictures. In your discussion you might want to consider the following:

- What are their clothes, homes and tools made of?
- How do the materials used compare?
- Which materials are natural and which are artificial?
- How and why have things changed over the years?
- Write down your conclusions and share them with other pairs of learners.

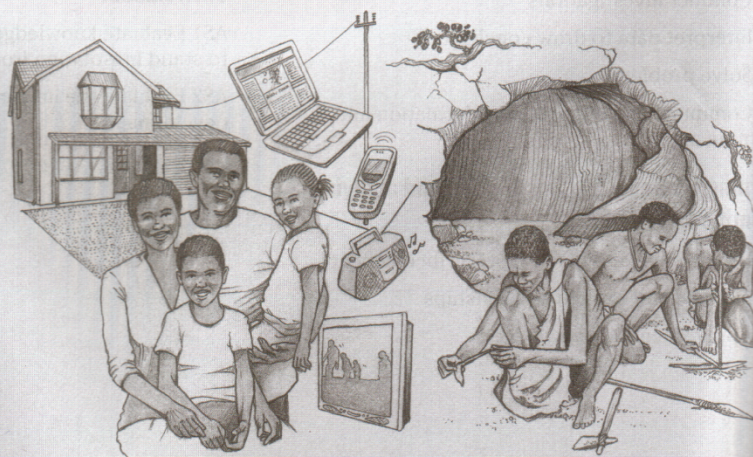


Figure 4.1: Modern-day and cave-dwelling families have different needs.

Some materials are made from only one substance, while others are **composed of a mixture** of different substances. Hardly any substances are

Analysis and discussion of the vocabulary usage in Sample 1:

Much of the scientific vocabulary introduced in these paragraphs is found in Level 3 of Wellington and Osborne’s taxonomy (see Box 3, below), the theoretical concept division of the taxonomy.

<p>Level 1: Naming Words</p> <p>1.1. Familiar objects, new names 1.2. New objects, new names 1.3. Names of chemical elements 1.4. Other nomenclature</p>	<p>1.1 1.2 1.3 silver, copper 1.4</p>
<p>Level 2: Process Words</p> <p>2.1 ostensive definition 2.2. no ostensive definition</p>	<p>2.1. 2.2.</p>
<p>Level 3: Concept words</p> <p>3.1 Sensory Concepts 3.2 Having dual meaning 3.3 Theoretical Concepts</p>	<p>3.1 solid, liquid, gas, metals, natural, artificial 3.2 materials, properties, substance, mixture, 3.3 matter, phases, macroscopic, pure,</p>

Box 3. Wellington and Osborne’s Taxonomy of Scientific Words

A number of non-technical words are found in the four paragraphs – ‘composition’ / ‘composed’ (used four times), ‘classifying’, ‘consists’ and ‘consistency’.

The meanings of difficult words are clarified:

- the word ‘natural’ is clarified with examples in brackets – ‘cotton’ and ‘wool’
- the word ‘man-made’ is clarified with an example given in brackets – ‘plastic’
- the words ‘completely pure’ are clarified by words ‘consists only of one substance’

- the word ‘composed’ is followed by the words ‘their composition’ which does not however, make the meaning of the word any clearer

The meaning of the word ‘material’, the comprehension of which is fundamental to the concepts being explained and those that follow, is further supported by Activity 1.

The explanation of the word artificial as something that is ‘made by man from scratch’ relies on an idiomatic expression which may be unfamiliar to readers who do not speak English as their home language.

The book has a comprehensive glossary. Words in the text that are bolded, (for example, ‘mixtures’, ‘metals’ and ‘pure substances’ in the above excerpt), can all be found in the glossary.

The extract from the gloss with respect to ‘mixtures’ reads:

A combination of substances in which the components retain their physical properties. They can be separated out by physical means.

The gloss however, uses difficult vocabulary. For example, the words ‘retain their’, is what Barnes (1973) calls the ‘language of secondary education’ and he suggests that it be avoided, as far as is possible, and that language be brief and concise (see Chapter 2, section 2.3.1.) and Williams (1989) cautions that a glossary should not contain words that are more difficult than the word being glossed.

The vocabulary found in the accompanying Activity 1, uses everyday language and this lowers the reading level. The reader is also drawn into the text and made an active participant, thus reducing the negative affects of the abstraction of scientific language.

1.2 Properties and uses of materials

The use of materials depends on their **properties**. Materials have both physical and chemical **properties**. **Physical properties** of materials include appearance, strength and the ability to conduct electricity or heat. **Chemical properties** are those involving chemical reactions of the materials. An example of a chemical property is flammability.

Activity 2 will help you think about the relationship between the properties of a material of which an object is **composed**, and its use.

Note

It is not only the material from which an object is made that gives it a particular property and use, it is also the shape in which it is made. Think about bricks – the shape of the brick allows us to place them closely on top of, and next to, each other to form a solid structure.

Activity 2 Linking properties of materials and objects with their use (groups)

LO2 AS2

The table below contains a list of objects whose **composition** is directly related to their use or purpose. Think about what each of these objects are made of and what they are used for.

List the properties of the materials that make it suitable for that specific purpose. Discuss in groups, then copy and complete the table in your work books.

Object	Made from (composition)	Used for (purpose)	Properties
Burglar bar			
Window frame			
Window			
Cooldrink can			
Car tyre			
Jersey			
Raincoat			
Pot			
Bridge			
Telephone wire			
Water pipe			

Dangerous materials

Some materials are dangerous. They are now used in small amounts and for a very specific purpose. For example, asbestos is heat resistant and does not rust, so it is a perfect material for roofing. However, long-term exposure to asbestos fibres can cause **asbestosis** – an incurable disease.

Benzene was used freely in dry-cleaners and in our homes to remove stubborn dirt and stains. However, benzene is **carcinogenic**, which means it has the potential to cause cancer. Therefore, the sale of benzene is now restricted.

Chlorofluorocarbons (CFCs) are substances that were used as aerosol propellants in deodorant sprays, in fridges and air conditioners. They contribute directly to the thinning in the ozone layer, which leads to increases ultraviolet (UV) radiation on the earth. This, in turn, increases the risk of skin cancer.

Mercury, the only liquid metal, is a perfect material to use for filling teeth. However, it was discovered that mercury is poisonous and that the fillings can erode over time. This can lead to the mercury **accumulating** in the body and result in mercury poisoning.

Analysis and discussion of the vocabulary usage in Sample 2:

Much of the scientific vocabulary introduced in these paragraphs (see Box 4 below) is found in Level 3 of Wellington and Osborne’s taxonomy (2001) (see Chapter 2, section 2.3.1.) and again at the theoretical concept level; however, the words are most often supported by an explanation of their meaning or are bolded to indicate that the word is to be found in the glossary.

<p>Level 1: Naming Words</p> <p>1.1. Familiar objects, new names 1.2. New objects, new names 1.3. Names of chemical elements 1.4. Other nomenclature</p>	<p>1.1. aerosol propellant, 1.2. asbestos, 1.3. mercury 1.4. asbestosis, benzene, chlorofluorocarbons, ozone layer,</p>
<p>Level 2: Process Words</p> <p>2.1 ostensive definition 2.2. no ostensive definition</p>	<p>2.1. chemical reaction, conduct electricity 2.2. carcinogenic</p>
<p>Level 3: Concept words</p> <p>3.1 Sensory Concepts 3.2 Having dual meaning 3.3 Theoretical Concepts</p>	<p>3.1 strength, flammability, 3.2 material, appearance, 3.3 chemical properties, physical properties, conduct electricity,</p>

Box 4. Wellington and Osborne’s Taxonomy of Scientific Words

The word, ‘material’, a theoretical concept, has been well established in the preceding paragraph ‘What are materials composed of?’

Activity 2, part of which is replicated below, actively links the word ‘properties’, another of the crucial concepts, to its conceptual meaning. The reader is directed to consider what an object is made from, link that to what it is used for and then further, note its properties. As

the activity is a group one, discussion among the learners will reinforce the connection between 'properties', 'purpose' and 'composition'.

The activity further uses every day language and common examples that the reader can relate to.

Object	Made from (composition)	Used for (purpose)	Properties
Burglar bar			
Window			
Car tyre			
Jersey			

The non-technical vocabulary is well supported in Activity 2, in that the non-technical word is bracketed but the every day meaning appears first.

4.2.2.2. ANALYSIS OF THE GRAPHICACY FOUND IN THE SAMPLED TEXT

4.2.2.2.1. SAMPLE 1 taken from Focus on Physical Sciences, Grade 10. 1st edn., 2008: 120

(SAMPLE IS ON THE FOLLOWING PAGE – PAGE 128)

Activity 1 Comparing materials used in ancient times with those used today (pairs)

LO2 AS3

Look at Figure 4.1. Have a discussion on the differences between the two groups of people and what you notice in the pictures. In your discussion you might want to consider the following:

- What are their clothes, homes and tools made of?
- How do the materials used compare?
- Which materials are natural and which are artificial?
- How and why have things changed over the years?
- Write down your conclusions and share them with other pairs of learners.

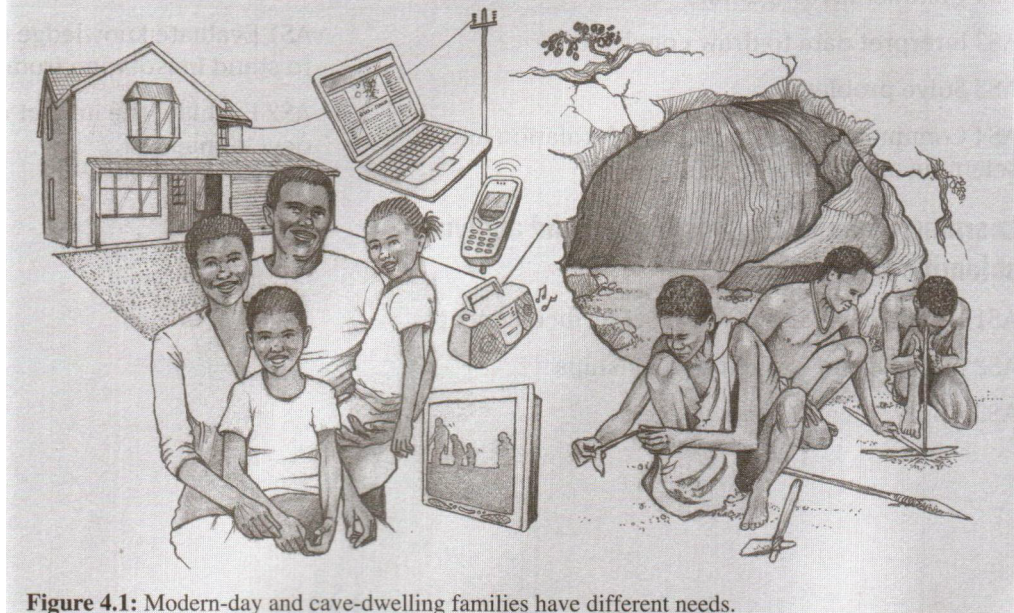


Figure 4.1: Modern-day and cave-dwelling families have different needs.

Figure 1 Sample 1 taken from Focus on Physical Sciences, Grade 10. 1st Edition

Analysis and discussion of the graphic:

The graphic is captioned (e.g. Figure 4.1) and is signaled to by the words 'Look at' in the accompanying text.

Further, the graphics are discussed in the text with explicit reference to how the reader should use them.

The graphics are clear representations of what the text refers to. Furthermore they serve to support the vocabulary as discussed above in section 4.2.3.3.

The activity draws on the background knowledge of the reader as the pictures are simple and part of every-day contexts.

4.2.2.2.2. Sample 2 taken from Focus on Physical Sciences, Grade 10. 1st edn., 2008: 121

Activity 2 Linking properties of materials and objects with their use (groups)

LO2 AS2

The table below contains a list of objects whose composition is directly related to their use or purpose. Think about what each of these objects are made of and what they are used for.

List the properties of the materials that make it suitable for that specific purpose. Discuss in groups, then copy and complete the table in your work books.

Object	Made from (composition)	Used for (purpose)	Properties
Burglar bar			
Window frame			
Window			
Cooldrink can			
Car tyre			
Jersey			
Raincoat			
Pot			
Bridge			
Telephone wire			
Water pipe			

Figure 2 Sample 2 taken from Focus on Physical Sciences, Grade 10. 1st Edition (2008:121)

Analysis and discussion of the graphic:

The graphic is signalled in the accompanying text.

Further, the graphics are discussed in the text with explicit reference as to exactly how the reader should approach the table and its uses.

The graphics are clear representations of what the text refers to. Furthermore they serve to support the vocabulary as discussed above in section 4.2.3.3.

The graphic contains simple vocabulary and uses examples that the grade 10 reader will likely relate to, for example 'car tyre' and 'window'.

4.2.2.3. ANALYSIS OF THE RHETORICAL STRUCTURES FOUND IN THE SAMPLED TEXTS

4.2.2.3.1. SAMPLE 1 taken from Focus on Physical Sciences, Grade 10. 1st edn., 2008: 120

The sample now analyzed and discussed is found above in section 4.2.2.1.1. :

All the paragraphs have a clear rhetorical structure, with purposeful signalling:

The chapter's heading: 'Composition, properties and uses of materials', is followed by an introductory statement that sums up the prior knowledge of the reader. This prior knowledge is also activated by the words: 'In your earlier studies...'

The heading of the first section is in the form of a question: 'What are materials composed of?' This purposeful use of signaling, makes the book 'considerate' of the reader, especially of the ESL reader (see Chapter 2, section 2.2.1.1.). The content of the paragraph that then follows the heading answers the question posed by the heading. The word 'materials' found in the heading is further repeated in the first sentence of the paragraph.

The topic sentence of the second paragraph is also the first sentence (see Chapter 2, section 2.2.1.).

The rhetorical structure is of a listing/descriptive type (Armbruster, 1986) and each addition to the initial description is well supported before the next is introduced.

The description of 'materials' follows a progression from the concrete and known, to the abstract. This 'step-wise' approach serves to decrease external cognitive load, thereby lowering the readability level of the book (see Chapter 2, section 2.2.5.3.).

The activity breaks the text to allow for the reader to participate actively in conceptualization of the word 'materials', before continuing to the more abstract meanings of the word.

4.2.2.3.2. SAMPLE 2 taken from Focus on Physical Sciences, Grade 10. 1st edn., 2008: 121

The sample now analyzed and discussed is found above in section 4.1.2.1.2.

The heading of the first paragraph is 'Properties and uses of materials'; and the topic sentence is the first sentence and it repeats the words found in the heading and further links them together: 'The **use of materials** depends on their **properties**.' (the words have been highlighted for the purpose of analysis)

The conceptual meaning of the word 'materials' has been well grounded (see section 4.2.3.5.1.) and as such, the reader will be ready for the second theoretical concept, namely that of properties.

This concept of 'properties' is then dealt with in a similar fashion to that of 'materials'; the schema is now familiar to the reader. This establishing of a constant rhetorical schema on the part of the author, is 'considerate' of the reader, as it trains the reader; and it helps to free the reader's WMC for the processing and linking of conceptual meanings and is constructive in lowering readability and increasing comprehension (see Chapter 2, section 2.2.1.1.). The reader is now in a position to link materials with properties in a meaningful way and to store this in his/her long term memory. Prior knowledge is linked with new knowledge and the knowledge storage system is 'updated' with the new.

The text is again broken with a meaningful activity where the connection between 'properties of' and 'uses of' is established. The link is reinforced by the reader's participation in a written and discussion activity.

The next sub-heading, 'Dangerous Materials', adds a dimension to the link between the properties of materials and their uses by an explanation of materials that have dangerous properties. The heading of this paragraph, the second paragraph in the sample, is again repeated in the first sentence of the paragraph. This first sentence is also the topic sentence.

Four materials are discussed, each in a separate paragraph with the more common terminology being linked to the chemical terminology, in other words: more concrete and known to abstract and new.

4.2.2.3.3. USE OF WORD BOXES TO CLARIFY AND AUGMENT THE TEXT

The book has 'note' boxes and 'How about this?' boxes.

- The note boxes are alongside the text in the margin (see Sample 2, section 4.2.2.1.2. above). These boxes are of a technical nature and reinforce understanding of a process or concept that is being developed in the text.
- The “How about this?” (see Figure 3, below for an example) boxes are interesting additions or snippets of information not always directly related to the main idea being constructed by the text. However, they are always placed at the end of a body of text, or before an activity, so as not to distract the reader from the important conceptual knowledge. When discussing the placing of ‘seductive details’, Mayer (1989) advises that these are best placed where they do not interfere with the main ideas being constructed by the text (see Chapter 2, section 2.2.3.).

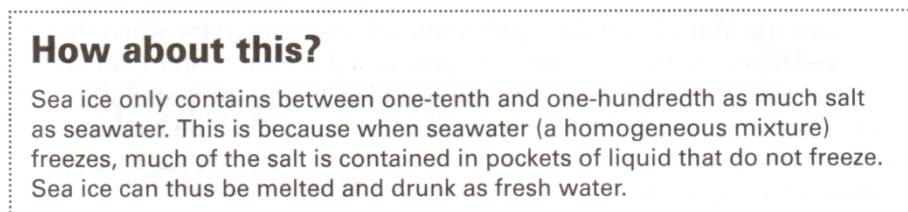


Figure 3: Example of a ‘How about this?’ box (Focus, 2008:124)

Furthermore the book has chapter summaries in three forms:

- A summary activity
- A summative assessment
- A comprehensive summary of the key concepts dealt with in the chapter

Summaries at the end of chapters positively aid in assisting the reader to consolidate what has been read (see Chapter 2, section 2.2.1.2.).

4.2.2.4. DECREASING COGNITIVE LOAD AND THE MANNER IN WHICH MULTI-LEVEL AND SYMBOLIC LANGUAGE IS PRESENTED IN THE TEXTBOOK

As discussed in Chapter 3, section, the solution chemistry of water is an area which involves the multi-level aspects of learning referred to in the review of literature (see Chapter 2, section 2.2.5.3.2.) and by the Content Document (see above in the introduction to the qualitative textual analysis).

The sample below (Focus, 2008:204) is now analyzed :

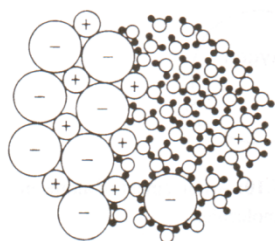


Figure 7.13: Diagram to show how salt dissolves in water.

Why does water form solutions?

Polarity also explains why water forms solutions. Other polar substances or ionic substances are able to dissolve in water. For example, table salt (NaCl) dissolves in water because it is an ionic compound made up of Na^+ ions and Cl^- ions. Look at Figure 7.13. Notice how the water molecules cluster round the Na^+ ions and the Cl^- ions. The hydrogen atoms of the water molecules, with their positive charge, are attracted to the Cl^- ions and the slightly negative oxygen atoms are attracted to the Na^+ ions.

Care has been taken to link the symbolic use of Cl^- and Na^+ with the words 'ions' and the symbol, NaCl with the words 'table salt'. Water is referred to as having 'hydrogen' atoms which have a 'slightly positive' charge and 'oxygen atoms' which are 'slightly negative'. The symbolic language of science, classified according to Wellington and Osborne (2001) as been the challenging and found in Level 4 of their taxonomy, is used sparingly with textual support.

Furthermore, the rhetorical structure of the excerpt scaffolds the reading process in a meaningful way. The question in the heading, 'Why does water form solutions?' is answered in the first sentence of the paragraph. The graphic accompanying the explanation is explicitly referred to in 'Look at Figure 7.13'.

Using ‘table salt’ as an example and linking it with its chemical formula of ‘NaCl’, brings chemistry down from the ‘level of frustration’ to that of the everyday, something a grade 10 learner will easily relate to. Merzyn (1987) (see Chapter 2, section 2.3.1.) argues that this aspect in science writing is very important when preparing textbooks for the novice science reader.

4.2.2.5. ALIGNMENT OF TEXTBOOK TO THE CURRICULUM

As has been reviewed in Chapter 2, the Curriculum Guidelines implemented in 2005/2006 have been criticized as being inadequate and opaque. The Review Committee reported that in some cases they contradicted each other and that the documents are not ‘user friendly’ (DoE, 2009:19-20).

A few examples of the ‘Core Knowledge and Concepts’ as per the NCS Physical Sciences: Content Document (DoE 2006) DoE document are now listed, followed by the author’s interpretation of each specific concept:

DoE document (2006:35) (see Appendix A):

- Describe an homogeneous mixture as a mixture with component parts that are indistinguishable from each other, like all in the same phase (the atmosphere is a mixture of oxygen, nitrogen, argon,...) or salt water.
- Give examples of common mixtures.

The interpretation of the author of the above (Focus, 2008:123):

“ **Homogeneous** mixtures have a uniform composition. The component parts of the mixture cannot be distinguished. Typically, the component parts are in the same phase or if one dissolves in the other, they form a homogeneous mixture. The air we breathe is also a homogeneous mixture of different gases, as shown in Figure 4.4.

The above excerpt is followed with a pie-graph depicting the proportion of the gases nitrogen, oxygen, noble gases, carbon dioxide and water vapour.

Discussion of the alignment of the text to the Content Document:

The book aligns comprehensively to the curriculum in its content and the depth into which it goes. The suggestions made by NCS Physical Sciences Grade 10-12: Content Document (DoE,2006) have been considered. For example, the Content Document suggests the use of 'air' as an example of a mixture and 'air' is given in the textbook. An attempt has been made to keep the examples simple but representative of the concept described.

Furthermore, the Content Document requires that 'an homogeneous mixture' be described as 'a mixture with component parts that are indistinguishable from each other, like all in the same phase' and the textbook expresses this as '**Homogeneous** mixtures have a uniform composition. The component parts of the mixture cannot be distinguished. Typically, the component parts are in the same phase...'

As readability involves the textbook, the reader and the reasons for reading, the alignment of the textbook to the curriculum cannot be ignored and the recommendations of the Review Committee call for "the production of excellent textbooks clearly aligned to the curriculum" (DoE, 2009:16) as being 'priority'.

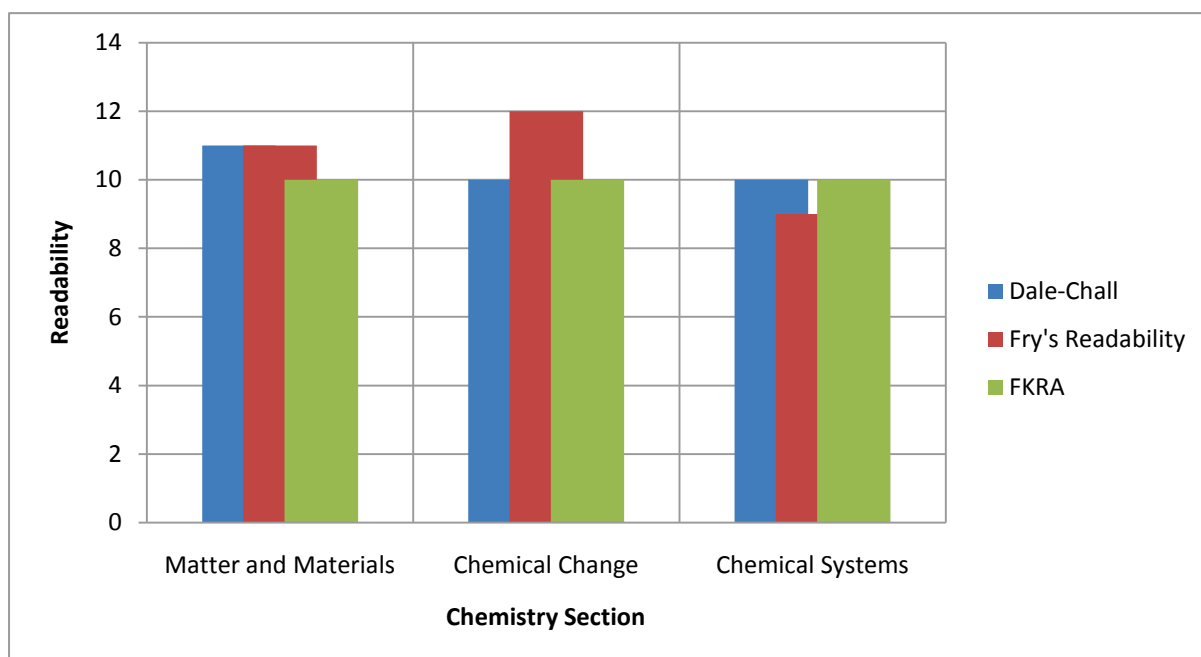
4.3. CASE STUDY 3: SUCCESSFUL PHYSICAL SCIENCE, GRADE 10 1st Edition (2008)

4.3.1. QUANTITATIVE DATA ANALYSIS – USE OF CLASSICAL READABILITY FORMULAE

As with Case Study 1 and 2, the three quantitative readability measures discussed in Chapter 3, section 3.4 were applied and the readability of each of the KAs in the text was calculated as well as the average readability of the three KAs. This allowed for a deeper insight into the readability of the book. The graphs below are drawn from the tabulated results of the sampling for the textbook as illustrated in Appendix B.

Graph 1: Comparison of the readability of the modules within the chemistry content

(Successful Physical Science, Grade 10)



Graph 2: Comparison of measures of central tendency of the three readability formulae

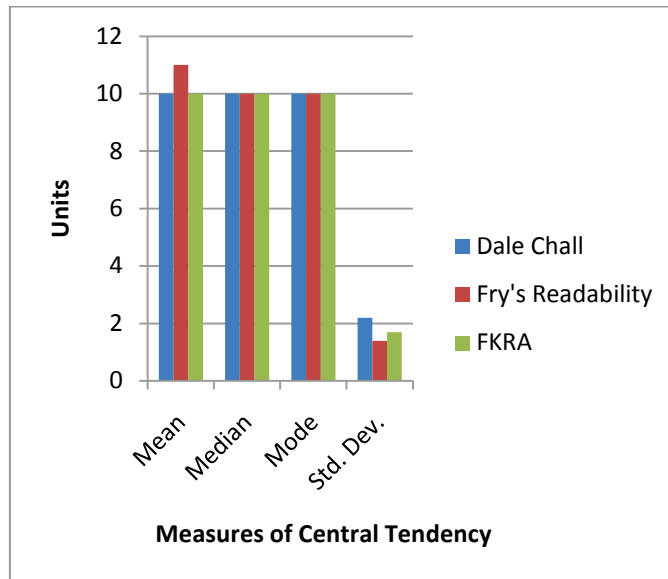


Table 1: Comparison of the measures of central tendency between the three readability formulae

	Dale-Chall	Fry	Flesch-Kincaid
Mean	10	11	10
Median	10	10	10
Mode	10	10	10
Std. Deviation	2.2	1.4	1.7

Discussion of the quantitative data depicted in the graphs and tables:

The data sets of the Fry Readability and the Flesch-Kincaid Readability Index are symmetrical; the mean and median are equal. The reading level for the chemistry section of the books is then at grade level 10 (refer Chapter 3, section 3.5).

The data set of the Dale-Chall Readability Formula is slightly skewed to the left as the mean is smaller than the median. The difference is significantly small at 0.3 and thus the reading level for the chemistry section of the books is read off at grade level 11 (see Chapter 3, section 3.5).

It is of interest to note that all three of the KAs have exactly the same grade level, grade level 10. The book has a uniform readability measurement according to the results reflected by the three readability formulae.

The correlation between Dale – Chall and Flesch-Kincaid Readability is .90 and the SD of the Dale-Chall, Fry Readability and Flesch-Kincaid Readability reflect that they correlate well.

4.3.2. QUALITATIVE DATA ANALYSIS

As in Case Study 1 and 2, two samples of the textbook were used to qualitatively investigate the cognitive-structural features of the book (see section 3.3.3. on the sample selection).

The samples were taken from the first chapter of the first KA: Matter and Materials.

The subdivision of the qualitative data analysis follows the same order as that used in the two case studies (section 4.2.1. and 4.2.2.) namely:

- Vocabulary used in the sampled text
- Graphicacy found in the sampled text
- Rhetorical structure of the sampled text
- Prior Knowledge Activation by the sampled text
- Level of Conceptual Difficulty of the sampled text
- Alignment of the sample of the textbook to the specific section of the Physical Science Content Document (DoE, 2006) guiding its structure

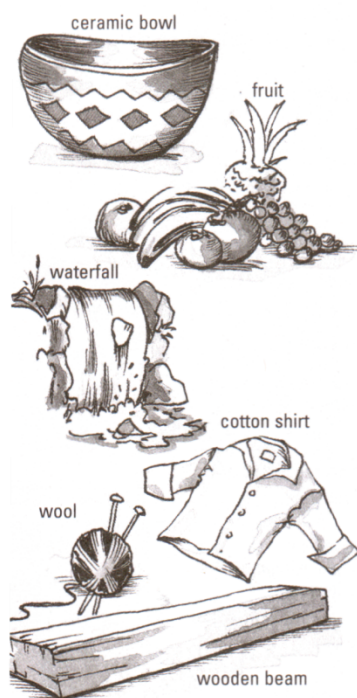
4.3.2.1. ANALYSIS OF VOCABULARY FOUND IN THE SAMPLED TEXTS

4.3.2.1.1. SAMPLE 1 taken from Successful Physical Science, Grade 10 1st edn.,
2008:82

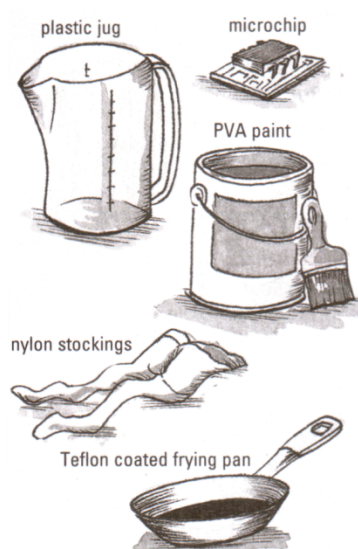
(SAMPLE IS ON THE FOLLOWING PAGE – PAGE 140)

UNIT 1

Matter and materials



▲ Fig 1 Examples of natural materials



▲ Fig 2 Examples of synthetic (man-made) materials

Matter and materials – what are they?

Matter is anything that has mass and occupies space. Matter and energy are the domain of the physical sciences, Physics and Chemistry. The biological sciences extend the study even further into the highly complex realm of living organisms.

Materials are the matter and substances from which things are made. Hence they are of vital interest to the physical and biological sciences, including medicine, as well as all engineering disciplines, furnishings and textiles.

Natural materials

From the earliest times, humankind has made use of the natural materials in the environment such as wood, fur, meat, water, fruit and so on.

The range of natural materials seems endless. New ones, such as complex substances in plants and animals, are constantly being discovered. This process is often assisted by local people – such as farmers, natural healers and sangomas – who have received the knowledge handed down through countless generations. This is called **indigenous knowledge**. It comes from observing how materials behave, describing what is observed and classifying it so that the knowledge is orderly and can be remembered. Often the knowledge is not written down but is remembered by means of stories and songs.

The discovery of scientific knowledge is not limited to the efforts of scientists in research laboratories. The farmer who keeps records of his computer-controlled irrigation, and the mechanic who detects unusual wear and tear of mechanical parts, for example, can also contribute to our scientific knowledge.

Human-made materials

Our knowledge and understanding of natural materials has enabled us to produce many materials that are not found in nature. These range from steel to artificial fibres, plastics, medicines and microchips.

Properties of materials

Materials can be described in terms of their properties such as:

- strength
- thermal (heat) conductivity
- electrical conductivity
- magnetic properties
- brittle (Does it break easily?)
- malleable (Can it be hammered into thin sheets?)
- ductile (Can it be drawn out into thin wire?)
- waterproof or not.

Analysis and discussion on the vocabulary usage in Sample 1:

There are a number of words that can be classified as Naming Words and a significant number of these are complex names (see Box 5 below). There are also a significant number of words that indicate theoretical constructs. ‘Matter’ and ‘materials’ is accompanied by a definition but the theoretical constructs of a ‘domain’ and a ‘realm’ will impair readability. Furthermore, the book does not have a glossary explaining the definitions of the words, so the reader will struggle to make sense of them.

<p>Level 1: Naming Words</p> <p>1.1 Familiar objects, new names 1.2 New objects, new names 1.3 Names of chemical elements 1.4 Other nomenclature</p>	<p>1.1 organisms, natural materials 1.2 materials, substances 1.3 1.4 physical sciences, Physics, Chemistry, biological sciences, medicine, engineering disciplines, indigenous knowledge</p>
<p>Level 2: Process Words</p> <p>2.1. Ostensive definition 2.2. No ostensive definition</p>	<p>2.1 2.2</p>
<p>Level 3: Concept words</p> <p>3.1 Sensory Concepts 3.2 Having dual meaning 3.3 Theoretical Concepts</p>	<p>3.1 3.2 3.3 domain, matter, mass, space, energy, realm, complex substances</p>

Box 5. Wellington and Osborne’s Taxonomy of Scientific Words

Everyday or high frequency words have been replaced with less common synonyms

- ‘occupies’ ... instead of... ‘takes up’
- ‘extend’ ... instead of... ‘take’ or ‘develop’

Logical connectives: 'Hence', 'including', and 'as well as' are all used in one sentence. The language of inference is one that Gardner (1977) (see Chapter 2, section 2.3.3.) recommends is used with care. The results of the SAQMEQ studies (see Chapter 2, section 2.4.2.4.) revealed that only 7% of the learners were able to read inferentially, highlighting the caution that must be used when preparing textbooks for the classroom.

Abstract nouns are used in the following two cases:

- the biological sciences, the physical sciences, engineering disciplines
- textiles and furnishings

The inexperienced reader will struggle to understand the abstraction and will likely not understand that 'textiles' refers to the clothing industry and 'furnishings' to the furniture industry. Concrete words are more readable than abstract words. For the ESL reader, one abstract word by itself, although less readable, is not likely to pose a major problem. But in association with other contributions to impaired readability like complex syntax and paragraph structure, one abstract word might be the decisive factor for comprehension (see Chapter 2, section 2.3.5.).

Two amplifiers have been used in the sample, 'highly complex' and 'vital'. Langhan (1990) gives guidelines on the use of amplifiers and suggests that care should be taken by writers to ensure that on the whole, intensifiers used are necessary and appropriate in meaning (see Chapter 2, section 2.3.5.). The use of 'highly complex' to add intensive meaning to the 'realm of living organisms' is likely to cause comprehension difficulties, especially for the ESL reader.

Prior research has shown that the words – 'occupy', 'classify' and 'constant' - categorized as non-technical are poorly comprehended, especially among ESL readers (see Chapter 2, section 2.3.2.). In this study, the comprehension of these words among first and ESL readers was tested (see section 4.4. below) and the results reflected the findings of prior research in that the words are still poorly understood, especially by the ESL readers.

Vocabulary is frequently supported by a bracketed set of words explaining the meaning of a word used. For example:

- thermal (heat energy)
- brittle (Does it break easily?)
- malleable (Can it be hammered into thin sheet?)
- ductile (Can it be drawn into thin wire?)

This glossing of words within the text is very effective in aiding comprehension, especially for the weaker readers (see Chapter 2, section 2.3.1.)

4.3.2.1.2. SAMPLE 2 taken from Successful Physical Science, Grade 10 1st edn., 2008:83

Matching properties to meet a need

Very often we make things to meet a need. For example, a biker wears a helmet for protection against injury. The properties of the materials that it is made of must fit the purpose of the helmet. It needs a rigid shell to spread an impact over the head instead of injuring a small part severely. It also needs a lining to increase the time that it takes to absorb the impact, as well as to make the helmet comfortable to wear.

An important part of designing a product is to:

- understand the composition and properties of a material
- choose or even invent materials that fit the purpose of the product.

Unintended properties

Sometimes such human-made materials cause problems of their own. For example, CFCs (chlorofluorocarbons) are human-made gases that liquefy easily and are ideal for refrigerators and air conditioners. It took years for scientists to discover that CFCs rise to the upper atmosphere of the Earth and react with the ozone in the ozone layer. Ozone is a gas that prevents dangerous frequencies of ultraviolet radiation reaching the Earth's surface. The ozone layer has become so much thinner that most countries, including South Africa, have pledged to reduce the use of CFCs.

A macroscopic view

A **macroscopic view** involves observing something with the naked eye (as opposed to a microscope), or considering large units at a time. The focus of this theme is to do just that. Nevertheless, we do not entirely ignore the **microscopic view**, that is, the approach that deals with the smallest units in matter. It becomes more and more important as an aid to understanding the properties of substances.

KEYWORDS AND CONCEPTS

indigenous knowledge, macroscopic view, materials, matter, microscopic view



▲ Fig 3 A wetsuit keeps the diver warm in the water. It is made of an artificial rubber called neoprene which is flexible and moulds to the body and allows movement. Trapped inside the neoprene itself are bubbles of nitrogen that are very good insulators of heat. Water that is trapped between the body and the wetsuit cannot move away and remove heat.

Analysis and discussion of the vocabulary usage in Sample 2:

The vocabulary is again classified according to Wellington and Osborne’s (2001) taxonomy of science words (see Box 6 below). There are a large number of theoretical concepts used.

<p>Level 1: Naming Words</p> <p>1.1 Familiar objects, new names 1.2 New objects, new names 1.3 Names of chemical elements 1.4 Other nomenclature</p>	<p>1.1 1.2 1.3 1.4 product, chlorofluorocarbons, ozone</p>
<p>Level 2: Process Words</p> <p>2.1. Ostensive Definition 2.2. No ostensive definition</p>	<p>2.1 liquify 2.2</p>
<p>Level 3: Concept words</p> <p>3.1 Sensory Concepts 3.2 Having dual meaning 3.3 Theoretical Concepts</p>	<p>3.1. rigid 3.2. 3.3. properties, materials, impact, frequencies, ultraviolet radiation, atmosphere</p>

Box 6. Wellington and Osborne’s (2001) Taxonomy of Scientific Words

Concept vocabulary must be used with care as this is the area of science, proposed by Wellington and Osborne (2001) (see Chapter 2, section 2.3.1.), where the most learning difficulties are encountered. Concept words denote ideas and are often part of a vertical network, i.e., the understandings of one word (such as power) depends on the prior understanding of other words (such as work and energy) and without prior understandings, the structure collapses. They note that many words can start as a name but, through language development in science, gradually be used as a concept. The concept word ‘impact’ denotes an idea and is part of the vertical network depending on prior understandings of other words. It is likely that grade 10 readers will not have access to the vertical network associated with the word ‘impact’, so impairing readability.

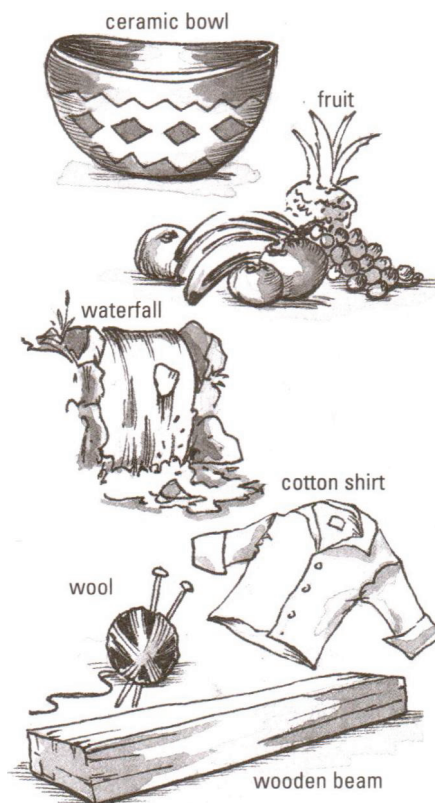
Some of the words, like 'materials' and 'properties', have been conceptualized in the previous section so should not pose difficulty for the reader. Others, like 'impact' and 'frequencies' are complex theoretical concepts that have not been explained earlier.

Some of the difficult vocabulary is followed by an explanation of the meaning of the word. For example the words 'macroscopic view' are followed with an explanation 'involves observing something with the naked eye' and 'microscopic view' is followed by the words 'deals with the smallest units in matter'.

The symbolic representation of the chlorofluorocarbon, CFC, is reinforced continually, assisting the reader in connecting the two representations – the word with the symbol.

4.3.2.2. ANALYSIS OF GRAPHICACY FOUND IN THE TEXTBOOK

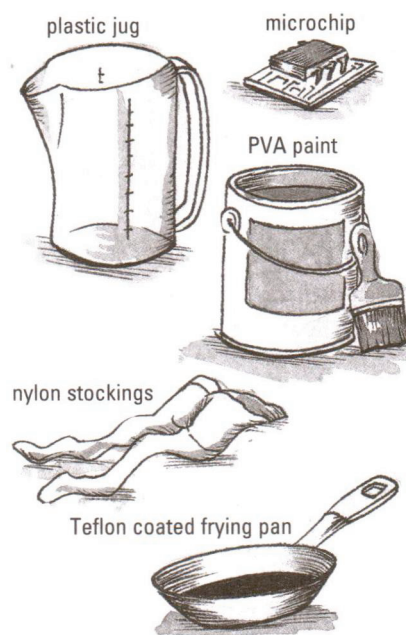
4.3.2.2.1. SAMPLE 1 taken from Successful Physical Science, Grade 10 1st edn., 2008:82



▲ Fig 1 Examples of natural materials

Analysis and discussion of the graphic:

The graphic has a caption, 'Fig 1 Examples of natural materials' and although the labels to the pictures, e.g. 'wooden beam' and 'waterfall' do not appear in the text alongside, the words 'wood' and 'water' do, making the relevance of the pictures quite clear to the reader.



▲ Fig 2 Examples of synthetic (man-made) materials

Analysis and discussion of the graphic:

Again the graphic has a caption 'Fig 2 Examples of synthetic (man-made materials)' and the individual pictures in the graphic are clearly labelled. However words describing synthetic materials, for example 'Teflon' and 'nylon' are likely to be foreign to the reader.

The word 'synthetic' is supported by its meaning given in brackets: 'man-made'. However, the lack of reference to the Figure in the accompanying text, together with the word 'synthetic' appearing for the first time in the graphic, weaken the assistance of the graphic to the reader. Graphics are more than just 'pictures' and carry a certain responsibility in the meaningful manner in which they support the accompanying text (see Chapter 2, section 2.2.4.).

4.3.2.2.2. SAMPLE 2 taken from Successful Physical Science, Grade 10 1st edn., 2008:83



▲ **Fig 3** A wetsuit keeps the diver warm in the water. It is made of an artificial rubber called neoprene which is flexible and moulds to the body and allows movement. Trapped inside the neoprene itself are bubbles of nitrogen that are very good insulators of heat. Water that is trapped between the body and the wetsuit cannot move away and remove heat.

Analysis and discussion of the graphic:

The graphic, captioned Figure 3, although a good example of the ‘matching of properties to meet a need’ theme of the accompanying text, is not referred to in the text. Furthermore, the caption explaining the picture is very detailed containing words like: ‘neoprene’ and ‘nitrogen’, naming words in the third level of Wellington and Osborne’s taxonomy of words (Wellington and Osborne, 2001).

As well as having to understand the challenging vocabulary, the reader would also have to understand concepts, for example that of heat transfer. The reader must understand that the thin water layer, trapped between the body of the diver and the wetsuit, has absorbed heat from the diver’s body. This ‘cognitive visualization’ must be held in the WM as the reader links this with the ‘bubbles of nitrogen trapped inside the wetsuit’ acting as insulators and so impeding the transfer of heat from the trapped water, thus keeping the diver warm.

4.3.2.3. ANALYSIS OF THE RHETORICAL STRUCTURE FOUND IN THE SAMPLES

4.3.2.3.1. SAMPLE 1 taken from Successful Physical Science, Grade 10 1st edn., 2008:82

The sample now analyzed and discussed is found above in section 4.1.2.1.2.

Analysis and discussion of the rhetorical structure of the sample:

The heading ‘Matter and materials – what are they?’ gives a good indication of what is to follow and incorporates a question which the following text answers. Both the words, ‘matter’ and ‘materials’, found in the heading, are bolded in the text and each signals the start of a short descriptive paragraph outlining the concepts. The topic sentence is the first sentence in each of these short paragraphs. This according to Sharp (2006) (see Chapter 2 section 2.2.1.1.), assists with comprehension and thus enhances readability.

However, ‘biological sciences’, ‘physical sciences’, ‘engineering disciplines’ are abstract concepts and these make comprehension challenging (see 2.3.6.). This then distracts from the main topic which could possibly have been better supported.

The sampled text then continues with ‘Natural Materials’. Again the heading is repeated in the first sentence of the paragraph. However, the main idea construction, that involved with the examples and uses of natural materials, is broken by a definition and examples of indigenous knowledge. Extensive research has been done examining the use of such distractions, known as *seductive details* and research findings show that adding seductive details (in the form of sentences) to a passage actually reduces students’ retention of the main ideas in a passage (see Chapter 2, section 2.2.3.). Also consistent with the seductive details hypothesis, is that readers typically remember interesting adjuncts included in a passage rather than structurally important ideas

4.3.2.3.2. SAMPLE 2 taken from Successful Physical Science, Grade 10 1st edn.,
2008:83

The sample now analyzed and discussed is found above in section 4.1.2.1.2.

Analysis and discussion of the rhetorical structure of the sample:

The heading of the sample is 'Matching properties to meet a need', follows directly after a description of properties of materials and the first sentence of the paragraph is then: 'very often we make things to meet a need'. An attempt is made to link the properties with purpose of materials.

The rhetorical structure of the sample follows a form / function pattern. (see Chapter 2, section 2.2.1.1.). For example, the biker's helmet needs to 'protect against injury' (its intended function), so it has a certain form namely, it is 'rigid'. Further, the helmet needs to provide 'comfort' so it has a soft lining.

The end of the paragraph links the form with function by suggesting that in designing products, the form of materials needs to be understood so that they can be chosen to perform a specific function when used in design.

There is a schema, that of form/function and there is some attempt at being explicit, however much must be inferred by the reader, a skill that is generally weak among grade 10 readers (see section above).

Comprehension of Sample 2 relies heavily on the reader's background knowledge of physics and the theories of collision. The word 'impact' has a specific meaning in association with 'force', 'momentum' and 'impulse', and the linking of 'rigidity' with 'spread of impact' and 'lining' with 'rate of absorption of impact' are both challenging cognitive concepts that the reader would need to understand to construct meaning and make sense of the concepts..

4.3.2.4. ALIGNMENT OF TEXT TO THE CURRICULUM

As has been reviewed in Chapter 2, the Curriculum Guidelines implemented in 2005/2006 have been criticized as being inadequate and opaque. The Review Committee reported that in some cases they contradicted each other and that the documents are not 'user friendly' (DoE, 2009:19-20).

A few examples of the 'Core Knowledge and Concepts' as per the NCS Physical Sciences: Content Document (DoE, 2006) DoE document are now listed, followed by the author's interpretation of each specific concept:

DoE document (2006:35) (see Appendix A):

- Describe an homogeneous mixture as a mixture with component parts that are indistinguishable from each other, like all in the same phase (the atmosphere is a mixture of oxygen, nitrogen, argon,...) or salt water.
- Give examples of common mixtures.

The interpretation by the author of the above (Successful Physical Sciences, 2008:86):

A homogeneous mixture has component parts that are indistinguishable from each other. The term is derived from the Greek word *homo* and means 'same'. They are in the same phase and you cannot see different parts.

Examples:

- The air we breath
- Sea Water

The author has almost repeated *verbatim* the Content Document in describing a homogenous mixture as having 'component parts that are indistinguishable from each other'. The Content Document suggests using salt water and air as examples and the author uses 'sea water' and 'the air we breath'.

It is clear that great care has been taken to care has been taken to align the textbook with the prescribed content for the Physical Sciences.

4.4. ANALYSIS OF THE COMPREHENSION OF NON- TECHNICAL VOCABULARY IN SCIENCE BY THE SAMPLE GROUP OF LEARNERS

The assessment of comprehension of non-technical vocabulary by grade 10 students using the textbooks was conducted in all three schools where focus-group discussions had taken place. One of the schools, School A is a former model C school where the both the home language of the students and the LoLT are English. The other two schools, School B and School C have students whose home language is Xhosa while the LoLT is English

The age of the learners was 15-16 at the time of the assessment. 25 words (listed in Table below) were chosen from the sample of 95 troublesome non-technical words used in the original work of Cassels and Johnstone (1985) (see Chapter 2 section 2.3.2.). These are words which a grade 10 Physical science teacher or textbook writer is likely to assume learners would readily understand and a copy of the questions used in the multiple choice test are in Appendix B. An example of the multiple choice question is given below:

The birds song was audible. This means it was

- E. very beautiful
- F. a long way off
- G. able to be heard
- H. made while flying.

Table 1 shows the facility value (FV = fraction of the class making the correct choice) for each word and also the most common distracters (wrong meaning). The results for the first and second language learners is set out separately. The set of questions appears in Appendix B.

An inspection of the table and graph of results (see Table 1 and Graph 1 below) show the following patterns:

In all the questions the FV for first language learners is much higher than that for the second language learners; in all the cases (marked with a *) the FV's were significantly different at better than the 5% level. For example, 100% (all) of the sample of English 1st

language learners comprehended the word 'limit' correctly, while only 40% of the ESL learners understood its meaning.

Distracters, which offered a 'sound alike' or 'look alike' word, were popular choices. For example, 'affect' for 'effect' and 'admit' for 'omit'. In the question testing the comprehension of the word 'effect', the word 'affect' was used as one of the choices. This then proved to be a distracter, indicating that readers confuse 'effect' and 'affect'.

Some strong distracters had the opposite meaning to the word under test. For example 'source' was given as 'where it went to' and 'abundant' indicated 'shortage'.

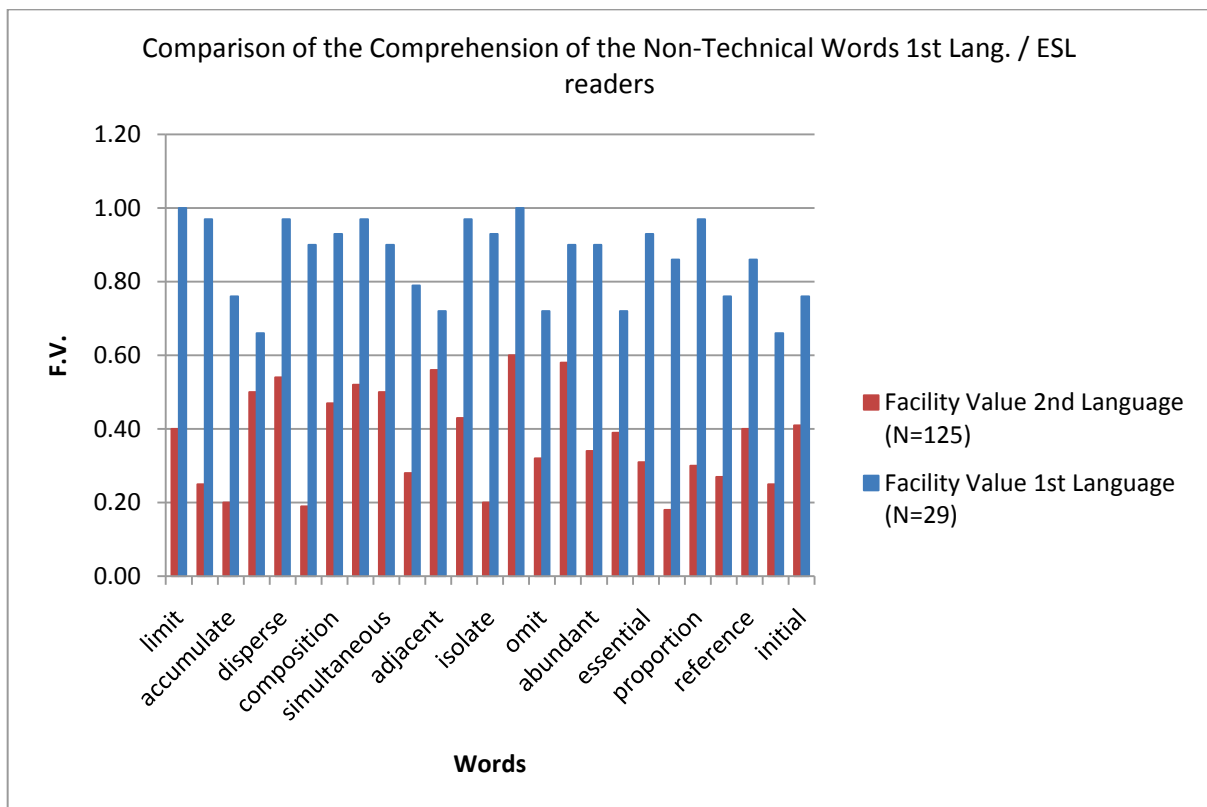
Some responses showed a distinct 'wooliness' in their meanings indicating that imprecise use of words, which have precise meanings in science. 'Limit' and 'percentage' appeared as average.

(Table 1 is on the following page – page 153)

Table 1 Results of the Comprehension of Non-Technical Words (1st and ESL readers)

Word	Facility Value 2nd Language (N=125)	Facility Value 1st Language (N=29)	Sig. Difference	Attractive Distracters
Limit	0.40	1.00	*	average,
Average	0.25	0.97	*	highest, higher than
Accumulate	0.20	0.76	*	Accommodate
Effect	0.50	0.66	*	Affect
Disperse	0.54	0.97	*	stayed on the ground
Contrast	0.19	0.90	*	Contour
Composition	0.47	0.93	*	Compensation
Source	0.52	0.97	*	where it went to
simultaneous	0.50	0.90	*	Similar
Consistent	0.28	0.79	*	constituent, consolation
Adjacent	0.56	0.72	*	Opposite
Illustrate	0.43	0.97	*	contain more information
Isolate	0.20	0.93	*	gave, discover the cause
Classify	0.60	1.00	*	Count
Omit	0.32	0.72	*	Permit
Percentage	0.58	0.90	*	average, a large number
Abundant	0.34	0.90	*	larger, shortage
Disintegrate	0.39	0.72	*	Disappears
Essential	0.31	0.93	*	
Estimate	0.18	0.86	*	Tell
Proportion	0.30	0.97	*	portion. Proposal
Efficient	0.27	0.76	*	Sufficient
Reference	0.40	0.86	*	deference, referee, quantity
Maximum	0.25	0.66	*	average, minimum
Initial	0.41	0.76	*	crucial, last
Mean F.V.	0.38	0.86		
Range	18-60	66-100		
SD	0.13	0.11		

Graph 1 Comparison of the Comprehension of the Non-Technical Words (1st /ESL readers)



All of these patterns were seen in Cassels' (1985) and Johnstone and Selepeng's (2001) original work which revealed that many of the words which teachers of science use at all levels are simply not readily accessible to their learners. Learners, when doubtful about the meaning of a word, are swayed by the context in which it appears and often take refuge in look-alike or sound-alike words. The learners' understanding of some words (for example, 'tabulate') was described by Cassels and Johnstone as 'disastrous'. Understanding of a large number of the words (for example appropriate, estimate, standard and essential) was deemed to be 'satisfactory'. However they reported that *very few* words were well understood.

The results (see Table 1 above) of the study conducted in this research reveal that the problem with understanding non-technical words in science still exists and that the problem is exacerbated for the second language learners. Among second language learners the general understanding of the words is alarming.

4.5. ANALYSIS OF FOCUS GROUP DISCUSSION

The focus-group discussions were held with the teachers in the three schools using the textbooks which are the focus of this study. One of the schools, School A is a former model C school where the both the home language of the students and the LoLT are English. The other two schools, School B and School C have students whose home language is Xhosa while the LoLT is English.

The analysis of the data is grouped under the sub-headings that guided the preceding qualitative textual analysis namely:

- Analysis and discussion of the vocabulary usage and possible challenges created by this
- Analysis and discussion of the graphicacy found in the texts and whether it is conducive to aiding the construction of meaning
- Analysis and discussion of the rhetorical structuring of the texts and features of the layout of the textbooks; and what effects these have on readability
- Analysis and discussion of comments pertaining to background knowledge activated by the texts and the effects of this on readability
- Analysis and discussion of the comments regarding case studies and the *Seductive Details* effect
- Analysis and discussion of the alignment of the textbooks to the NCS Physical Sciences: Content Document (DoE, 2006)

4.5.1. AN ANALYSIS OF COMMENTS MADE REGARDING THE VOCABULARY OF THE TEXTBOOKS AND THE EXTENT TO WHICH THIS IS A PROBLEM

Vocabulary in the textbooks, both scientific and non-technical, makes them difficult to read and mediate in the classroom. At School A where the learners are Home Language English learners the teachers acknowledged that they “have to use the correct vocabulary and science vocabulary” when teaching but that the textbook fails them when too much of this vocabulary is “not properly explained and supported”. They described the problem as one affecting both first language English and ESL learners.

For the ESL learners, the vocabulary difficulties are exacerbated in that teachers find that the learners are not prepared for the linguistic challenges of studying science in English in grade 10. As one teacher commented of the learners that “they don’t speak English well and understand well” while another added that as teachers they cannot “start in grade 10 with difficult terms and language” but need to use basic English.

They acknowledged the need to code-switch to give relief to the continual struggle with the language and to clarify concepts for learners. This need is given voice in the following comment: "our learners they are taught physical science in English but since we are the Xhosa speaking teachers it is not easy for us as teachers to teach the whole period in English. We have to go back to Xhosa so as to make sense of the material so I use code switching all the time to the extent that on the notes I give them opportunity to write in the Xhosa."

The learners themselves find the vocabulary frightening and are “running away from physical science because the language is so difficult”. Their requests that Xhosa be spoken in preference to English by the teachers, bears evidence to their struggle with the language and the likely WMC overload they continually experience.

The problems experienced by the teachers and learners are those that Probyn (2006) (see Chapter 2 section 2.4.3.1.) notes when she comments that the poor English language skills of the majority of learners in township and rural schools militate against teachers and learners strictly adhering to English as there is a gap between learners’ English proficiency and the linguistic demands of learning through the medium of English.

The glossary is one solution that the teachers have found helps to partially resolve the vocabulary problem and deficit for both first and second language learners. On a number of occasions the assistance provided by the glossaries was raised.

The words that have dual meanings remain a challenge for learners especially when the word in question is also a concept word. Then teachers need to explain the concept while continually reinforcing the word. The words ‘equilibrium’ and ‘weight’ were mentioned and

as one teacher put it “what has one meaning, has two meanings”. The teachers need to clear up the misconceptions and the often contradictory information that learners have derived from the every day meaning of a word. This challenge is expressed in a comment by one of the teachers when she explained that “there are concepts like equilibrium...you can get equilibrium in English, you can get equilibrium in Geography, even in Physics, even in Life Sciences but the way it is written is the same but it has a different meaning in each and every subject.” Thus the words with dual meanings need to be well supported in the textbooks.

Teachers explained that learners are often able to read “all of the vocabulary” without comprehending meaning and that this is evident when they allow the learners to read independently and then try to initiate a discussion on what has been read.

The poor reading skills of the learners are a further inhibiting factor as learners tire mentally after only reading “for a short while”.

4.5.2. AN ANALYSIS OF THE COMMENTS MADE REGARDING THE GRAPHICACY FOUND IN THE TEXTS AND HOW THIS EFFECTS THE READABILITY OF THE TEXTBOOKS

That role of graphicacy has been reviewed in Chapter 2 (see section) and is a feature that should significantly lower readability.

However, poor graphicacy has impaired readability as the comment below clearly establishes:

“The graphicacy in our former textbook or the textbook recommended by the Department isn’t clear. Some of the diagrams are far too complex and put the pupil off before they’ve even started. Mind maps, diagrams and pictures need to be relevant and they often aren’t. They are not supported by the text. They are pictures filling places and making the book “look nice”. This helps with the marketing maybe but not in the classroom. It proves to be a hindrance.”

The ESL learners are particularly dependent on graphicacy when reading their English expository textbooks and teachers commented on this fact. They noted that “the sketches are very important to integrate what they’ve [the learners] read” and that the learners use this text and picture combination to construct conceptual meaning. They noted that when the graphicacy fails this vital pedagogical tool is lost to them.

4.5.3. AN ANALYSIS OF THE COMMENTS MADE PERTAINING TO THE RHETORICAL STRUCTURE FOUND IN THE TEXTS AND HOW THIS EFFECTS THE READABILITY OF THE TEXTBOOKS

‘Considerate’ rhetorical structuring is very important in lowering the readability level of science texts. A explicit schema and clear signaling in effect ‘frees’ WM space and allows the reader to focus on the cognitive complexities involved with understanding science.

However, the teachers using the textbooks under study often struggled to mediate these because of poor rhetorical structure and the introduction of concepts in an ‘inconsiderate’ way. It was commented during the focus-group discussions that ‘textbooks have a way of “jumping in” with a concept without clarifying or explaining them. They tend to simply use the concept as though the pupil would understand what they are talking about. They “start” ... launch into a topic or concept without giving it background or proper attention.’ The example that the teacher then mentioned was that of ‘magnetic flux’, a physics concept but the comment is general in that often these ‘extremely difficult and unfamiliar concepts’ are clearly not given consideration by the writers because ‘the textbook just uses the term, assuming the learner is familiar with it. The writer doesn’t take the trouble to first bring it to the level of the learner and then build from there.’

The ESL teachers explained the problem with rhetorical structuring by noting that the textbooks have ‘a lot of notes and not a lot of simplification...for each and every concept’ and this makes the textbook too difficult for the ‘learners that are not so bright, the strugglers’.

Another comment concerns the general layout of supporting examples and exercises. A teacher mentioned that “the layout of the textbook is not user friendly with sufficient examples. The books have some worked examples but insufficient examples for the learners to do and practice. The problems are often inappropriate and of an incorrect standard.” At this particular school, the science department had rejected the textbooks on the recommended list by the DoE and were using another textbook. Their comments in favour of this book reflect what they need in a textbook: “The book which we find works better for us is [a] workbook. Here, in this book, the concepts are clearly explained and summarized and then there are step-by-step problems for the learners. The problems take the learners through each concept in a progressive way making them do problems which reinforce the concept.”

4.5.4. ANALYSIS MADE OF COMMENTS PERTAINING TO THE BACKGROUND KNOWLEDGE OF THE LEARNERS AS WELL AS THE PRIOR KNOWLEDGE ACTIVATED BY THE TEXTS AND THE EFFECTS OF THIS ON READABILITY

The activation of background knowledge by the text is very important because new knowledge is constructed with the support of prior knowledge. It is also linked to prior knowledge when stored and the knowledge structure is thus formed.

In this regard, the teachers all referred to the problem created by the mismatch between the grade 9 and the grade 10 curricula. This problem is addressed in the Chapter 2 (see section). Learners come to grade 10 with a deficit of science knowledge because of the poor contributions made by grade 8 and 9 curricula. One teacher succinctly summed up the problem when she noted that the learners will be “playing with many things which are different and not previously learned”. This makes teaching the grade 10 content extremely difficult and naturally impacts on the readability of the textbooks and this is so clearly reflected in the following comment that “there is insufficient time is given to physical science. Life sciences are given more attention as teachers are more comfortable with Life Sciences but the Physical Sciences are often poorly taught. Certain concepts aren’t taught or are incorrectly taught and this makes it difficult to teach the grade 10 curriculum.”

The teachers in schools where learners come in grade 10 from ‘feeder schools’ have an even greater problem. The knowledge that these students have is completely inadequate to the task and it is very difficult to make up the deficit while attempting to teach new content and stay abreast of the learning programme.

Teachers’ commented that as “the books assume a background knowledge that the learners do not have”. it would assist them greatly “to have a summary at the beginning of a chapter just wrapping up the background knowledge necessary to continue with the concepts. We could then revise those first and then continue.”

Literacy is a problem. We are teaching learners with a lot of backlog. We are doomed. Because whatever we are trying to do, we are trying the impossible because we have learners that are already having problems. If a learner missed some concepts it is very difficult when that learner is in high school to catch up.

4.5.5. ANALYSIS OF COMMENTS MADE REGARDING THE ROLE OF THE LAYOUT OF THE TEXTBOOKS AND HOW THIS AFFECTS THEIR ACCESSIBILITY

The general layout of the textbooks was also discussed and in this respect the teachers spoke of the advantage of print being clear and the font being comfortable and easy to read. They referred to the font size and type in certain of the textbooks as being ‘uncomfortable’ and recommended a bigger, bolder print. They noted that large ‘chunks’ of unbroken text tire the novice readers and raise the readability level of the textbooks.

The feature that the teachers again highlighted as being conducive to lowering the readability and making the textbooks accessible, were the glossaries (already mentioned on numerous occasions). On the issue of glossaries one teacher cautioned the need to keep the language in these simple and inclusive of all concepts and expressed problems with the current glossaries in that the language is “not so simple”.

Glossing words within the text was also mentioned as being positive in making the textbooks accessible to the apprentice science readers. A teacher commented that when

they (the authors) “are writing...the textbooks...they can put in brackets sometimes, some of the meanings” and she added that “even a glossary having Xhosa or Zulu terms” would be most helpful.

There was the suggestion made of the need for a ‘summary book’. The teacher explained it as a “...summary book that goes with the textbook. Not like an exam bank with the previous question paper... but a book that will summarize”. Short chapter summaries were also highlighted as assisting in lowering the reading level of a textbook.

4.5.6. ANALYSIS OF THE COMMENTS RELATING TO THE USE OF ‘CASE STUDIES’ AND ‘SEDUCTIVE DETAIL’ IN THE TEXTBOOKS AND THE EFFECTS OF THESE ON READABILITY

Seductive details were reviewed in Chapter 2, and are described as highly interesting and entertaining pieces of information that are only tangentially related to the topic and may be irrelevant to the author’s intended theme (Garner, Brown, Sander, & Menke, 1992; Gamer et al., 1989). However, Harp and Mayer, (1997) note that students often find the material in expository textbooks boring and textbook writers, in an attempt to avoid this, resort to adding *seductive detail* to increase students’ interest in a text.

On the issue of these *seductive details* and also the often involved case studies found in the textbooks, the teachers commented that although some content is “nice to have”, they did not have time for it and that “it cluttered the text and distracted the learners”. They even felt that “enrichment was something that” they could “source” on their own and it is better if the textbook was simply more functional.

Teachers noted that the learners cannot often distinguish “between what is important and what is irrelevant” and that it is here where *seductive details* can be dangerous in their distracting of the reader’s attention from the main ideas in the text. This danger was highlighted by a number of researchers (Gamer, Alexander, Gillingham, Kulikowich, &

Brown, 1991; Garner et al., 1992; Garner et al., 1989; Harp & Mayer, 1997; Hidi & Baird, 1986; Wade, 1992; Wade & Adams, 1990).

The ESL learners have a struggle reading the case studies and the teachers noted that they have to take time to mediate these; time which they feel they do not have.

It was also mentioned in the focus-groups that teachers have to “experience” the textbooks before they can guide the learners in their reading and when the textbook is full of excess information, this effort “simply takes up too much time and so the book is discarded”.

4.5.7. ANALYSIS OF THE COMMENTS MADE REGARDING THE ALIGNMENT OF THE TEXTBOOKS TO THE CURRICULUM AND THE HOW THIS ALIGNMENT AFFECTS READABILITY

The alignment of the textbook with the curriculum content documents is something that teachers regard as most important. Teaching is what they need to do and the time constraints, especially in the last phase of secondary school, are such that they need reliable LTSM to guide them in the content needed for the final qualifying examination.

However, this is difficult as textbooks are varied as to their elaboration of the Physical Science Chemistry content. The comments in this regard were that there is “insufficient time given to the development of the current textbooks. They are obviously being written with deadlines. Some were written before the curriculum was published and so are misleading in their depth and their content. This problem makes it impossible for us as teachers to “trust” as textbook.”

The necessity of the textbooks goes unquestioned by the teachers and one commented of her students that “they need the text book! We can’t do notes in the class. We have to use our textbook. When they have a new section...yes the textbook is a big help. There are teachers that are behind because they do not have enough textbooks. We need our textbooks to make progress. The textbook helps us to keep up with the work schedule.”

4.6. CONCLUSION

The analysis of the textual data of each of the three case studies, beginning with the quantitative data and then progressing to the qualitative data, the quantitative results of the multiple choice test that assessed the comprehension of non-technical words by the students using the textbooks and the qualitative data gathered during the focus-group discussions with the teachers using the textbooks is now further discussed in Chapter 5: Discussion of Findings.

In discussing the findings of the data analysis, I return to the research question: 'How readable are the grade 10 chemistry textbooks?' and seek to answer it, in the light of the data gathered and analyzed.

CHAPTER 5

DISCUSSION OF FINDINGS

This study has sought to answer the question: “How readable are the grade 10 Science textbooks?” As discussed in Chapter 2, ‘readability’ is dependent on the text, the reader and the context within which the text is read.

In Chapter 3, I noted my choice of a concurrent mixed methods research design (see Chapter 3, section 3.2) and in Chapter 4, documented the analysis of both the qualitative and quantitative data. As the design is a convergent parallel design, it is during this final interpretation phase, when I discuss the findings emerging from the analysis, that I allow for the integration of the results to get a clear overall picture. It is here where convergence or divergence is noted and discussed.

The data analysis related to each of the textbooks studied is discussed with reference to both the qualitative (cognitive-structural) and quantitative (classical) data and emphasis is placed on the integration of these two strands.

This is followed by a discussion of findings related to:

- the reader
- the comprehension of the non-technical words used in science, and
- the classroom mediation of the textbooks.

Finally, the chapter concludes with recommendations arising out of the study and a discussion of some limitations of the research.

5.1. CASE STUDY 1: *PHYSICAL SCIENCES FOR GRADE 10* 2ND EDITION (2008)
(THE STUDY & MASTER SERIES)

5.1.1. DISCUSSION OF THE READING LEVEL OF THE TEXTBOOK AS PREDICTED BY THE
CLASSIC READABILITY FORMULAE

The classic readability results indicate that the text is at a grade 11 reading level, a reading level above the grade level for which it has been written. For the KA, 'Chemical Change', a cognitively challenging section of grade 10 chemistry, the readability formulae reflect a range of reading level scores, from a grade 11 level to a grade 13 reading level. The reading level is clearly above the grade for which the textbook has been written.

It should be noted, as discussed in Chapter 3, section 3.4.4., that the formulae used in this study – like reading tests – do not have a common zero point (Klare, 1982). They are based on combinations of different variables, as well as different criterion scores used in their development. Those developed with the higher criterion scores tend to predict higher scores, while those with high validity correlations, for example, Dale-Chall and Flesch, tend to predict lower scores. We can assume that the Dale-Chall reading (grade 11) as well as that of Flesch-Kincaid (grade 10), are more than likely lower than the actual readability level of the sampled texts.

The matter of optimum difficulty (see Chapter 3, section 3.4.5.) needs to be considered. Bormuth (1966) suggests that when texts are supported by teacher mediation, they should be slightly above the level of the reader. This would suggest that a higher reading level is acceptable where the textbook is intended to be used in class with the support of the teacher.

However, the following two points need to be fore-grounded when making decisions regarding optimal difficulty in the case of the texts studied:

- the literature reviewed (see Chapter 2, section 2.4) points conclusively to the reality of the reading level in the ESL grade 10 classrooms being at least a grade, if not two grades, below that of the expected grade 10 level.

- the teachers (see Chapter 4, section 4.5.) struggle to mediate the textbooks in the classroom.

Paul (2003) (see Chapter 3, section 3.4.5.) notes that for independent reading a 92% comprehension is necessary for advanced readers. This would suggest that unless the book is well mediated in the classroom, which it is not (see section 5), it would necessitate independent reading on the part of the student. The ability or skill of the grade 10 reader in the context of this research to meaningfully comprehend the textbook under discussion, independently of mediation, is highly questionable.

To gain a deeper insight into its readability, the cognitive-structural aspects of the textbook are now discussed.

5.1.2. DISCUSSION OF THE COGNITIVE-STRUCTURAL READABILITY ASSESSMENTS AND THE READING LEVEL OF THE BOOK

5.1.2.1. THE ROLE PLAYED BY VOCABULARY IN RAISING THE READING LEVEL OF THE TEXTBOOK

The vocabulary used in the book places it at a reading level easily a level or two above the grade 10 level. The vocabulary in the KA, 'Chemical Change' is at level 13, which is regarded as college level. One would expect the vocabulary to be cognitively challenging since this is a characteristic of the language of science, yet there are ways of compensating for this that have not been addressed. In this regard:

- There is no glossary in the book, neither is there any attempt to support vocabulary with bracketed meanings. The graphicacy and diagrams which could support and give clarity to vocabulary, instead work contrary to this, further confusing the reader (see Chapter 4, section 4.1.2.1. and 4.1.2.2.).
- Conceptual words are not supported in a meaningful way whereby the concept is 'labelled' and then explained and reinforced. The meanings of concept vocabulary is further blurred in that:

- Referent terms are used interchangeably when describing concepts. For example, the words ‘matter’, ‘materials’, ‘substances’ and ‘objects’, are all used to refer to a single referent before its conceptual meaning has been established (see Chapter 4, section 4.1.2.1.).
- Concepts and scientific nomenclature are introduced without an explanation. One such example is that of solutions listed as ‘tincture of iodine’ and ‘rubbing alcohol’ (see Chapter 4, section 4.1.2.1.2.).

5.1.2.2. THE ROLE PLAYED BY GRAPHICACY IN THE READING LEVEL OF THE TEXTBOOK

Graphicacy is another ‘tool’ that can be used to mediate a high density of scientific concepts and associated vocabulary by using visual aids to give clarity to the meanings of complex concepts and terms (see Chapter 2, section 2.2.4.).

However, the graphicacy in the text fails to fulfil this role for a number of reasons:

- Diagrams, pictures and flow-charts are not captioned and then referred to in the accompanying text with clear use of signalling to prompt the reader to reference the graphic.
- The diagrams are not explained in the accompanying text or even referred to, resulting in the diagrams standing apart from the text, to the reader.
- The use of graphics that are cognitively above the level of the learner inhibits readability.
- The use of a symbols to depict atoms or molecules with no textual explanation of their meaning adds to the difficulty of the text.

As discussed, graphicacy is important in a science text for clarifying concepts and procedures, for supporting vocabulary and for bringing abstract concepts to a concrete level. Furthermore, when considering the need to decrease cognitive load, especially with respect to multi-level learning (see Chapter 2, section 2.2.5.3.2.), illustrations play an important role. Pictures and diagrams that perform these functions well assist in

making the text accessible, especially for readers who are reading in their second language.

The points noted above, reveal that the graphicacy accompanying the text is likely to impair readability, instead of playing a supportive role.

5.1.2.3. THE ROLE PLAYED BY RHETORICAL STRUCTURING IN RAISING THE READING LEVEL OF THE TEXTBOOK

The lack of rhetorical structuring and signalling is another aspect of the book that fails the reader. The literature reviewed (see Chapter 2, section 2.2.1.) points clearly to the need for explicit rhetorical structuring and clear signalling. The conceptual load in science is sufficiently challenging for the novice and clear rhetorical schema are important in helping to alleviate this load. Readers who are learning science in a language not their own are particularly vulnerable to problems caused by texts with a poor rhetorical structure. Their working memory capacity (see Chapter 2, section 2.2.5.3.1.) has to deal with translation to mother tongue, retrieval of prior knowledge and processing of new concepts. If, in addition, readers have to impose their own structure on the text, this creates significant overload and comprehension is greatly reduced.

The placing of topic sentences, in the case of a paragraph having one, towards the end of a paragraph is another weakness in the text impairing readability (see Chapter 2, section 2.2.1.1.).

The implicit nature of definitions is another serious impairment to the readability of the textbook. As reviewed in the literature (see Chapter 2, section 2.2.1.2.), second language learners expect and need the 'text to tell them everything'. Definitions need to be explicit and not masked by examples or obscure references. A concept, once defined, should remain named as such and not have the name replaced by a referent before the reader has had time to process the concept linked to that particular name.

5.1.2.4. CONCEPTUAL PROGRESSION AND THE READING LEVEL

Little consideration is given to explaining a concept before using it to build a related concept. This occurs continually through the text, leaving readers swimming in a sea of unconnected concepts, thus encouraging them to create alternative frameworks for these concepts (see Chapter 2, section 2.2.5.3.1.).

This is further noted in the examples in the Data Analysis section (see Chapter 4, section 4.1.4.1.6.) where the reader is taken into the 'middle' of the conceptual triangle. The text moves rapidly from macro-to-micro-to- symbolic-language. This greatly increases the internal cognitive load and impairs comprehension (see Chapter 2, section 2.2.5.3.2.).

Little effort is made to assist the reader in accessing background knowledge before a concept is explained.

5.1.2.5. GENERAL LAYOUT OF THE TEXTBOOK AND ITS EFFECT ON READING LEVEL

The textbook has a poor layout. This is noted in:

- a. the lack of chapter summaries, glosses and a general glossary
- b. headings that do not prepare the reader for the text to follow
- c. long sections of unbroken text
- d. inappropriate use of 'Did you know?' boxes

5.1.3. THE RAISED READABILITY LEVEL OF THE TEXTBOOK AS A RESULT OF MISALIGNMENT TO THE PRESCRIBED CURRICULUM

The NCS Physical Sciences Content Document has been criticised for being obscure (see Chapter 2, section 2.4.5.) and it has been noted that this document (see Chapter 2, section 2.4.4.) gives authors and teachers a wide scope as to the depth that they feel necessary when addressing content. The Study & Master 'Physical Sciences for Grade 10' is not well aligned to the curriculum document and often extends the curriculum beyond the cognitive level of the intended reader. This serves to lift the readability level of the book well above that of grade 10 learners. It also makes mediation of the textbook by the teacher difficult.

5.1.4. THE TEACHERS' VIEWS ON TEXTUAL READABILITY PROBLEMS

The analysis of the focus group discussion data reveals that the teachers struggle to mediate the book in both first and second language contexts. All of the impairments to readability discussed above were reconfirmed by the teachers (see Chapter 4, section 4.5.). The problem is, however, exacerbated in the second language classes where teachers confessed to finding it almost impossible to mediate the textbook. These teachers refer to it as a book for the 'gifted' learner acknowledging that few of their learners fall into this category.

5.1.5. CONCLUSION

The discussion of the quantitative data analysed reveals that the textbook is above the level of the grade 10 reader in the South African classroom and the discussion of findings of the qualitative data, firmly supports that of the quantitative measure. The two triangulate well (see Chapter 3, section 3.2).

In returning to the research question: 'how readable is the chemistry section of the textbook?' it is evident that the book fails as an adequate teaching and learning resource for grade 10.

5.2. CASE STUDY 2: *FOCUS ON PHYSICAL SCIENCES, Grade 10. 1st Edition (2008)*

5.2.1. DISCUSSION OF THE READING LEVEL OF THE TEXTBOOK AS PREDICTED BY THE CLASSIC READABILITY FORMULAE

One of the reading formulae locates the book at grade 10 level whilst the other two locate the book at reading level 11 and 12, both above the grade 10 reading grade level.

The KA: Chemical Change section, is found to be two to three levels above the reading level for grade 10.

As discussed in section 5.1.1. above, the optimum difficulty level for the grade 10 textbook should be that of a grade 10 level, especially in view of the fact that:

- The reading level of the students is below average.
- Most of the students are reading in their additional language.
- There is difficulty in mediating the texts in the classroom.

However as reviewed in Chapter 2 (see section 2.7.), the classical and cognitive-structural paradigms work together to give a clearer picture of readability and thus the cognitive-structural aspects of the textbook are now discussed.

5.2.2. DISCUSSION OF THE COGNITIVE-STRUCTURAL READABILITY ASSESSMENTS AND THE READING LEVEL OF THE TEXTBOOK

5.2.2.1. THE ROLE PLAYED BY VOCABULARY IN RAISING THE READING LEVEL OF THE TEXTBOOK

Although the reading formulae reveal that the book has a high level of difficult vocabulary, every attempt has been made to support this vocabulary.

- a. The book has a comprehensive glossary and words that appear in the glossary are highlighted in the text, alerting the reader to the support option of the glossary (see Chapter 4, section 4.2.1.1.).
- b. Difficult words are very often immediately followed by bracketed meanings or an explanation of the meaning of the word.
- c. The graphicacy aids in the explanations of words and the activities make a special point of engaging the reader in actively 'making meaning' of difficult vocabulary and concepts. An example of this is the linking of materials to their composition and then to their use, giving the reader an opportunity to link the three together cognitively (see section 4.2.3.1.2.).

5.2.2.2. THE ROLE PLAYED BY GRAPHICACY IN THE READING LEVEL OF THE TEXTBOOK

As mentioned in Section 5.1.2.2. above, the *graphicacy serves to support both vocabulary comprehension as well as conceptual understanding of words*. Consideration is given to the intended readers' possible lack of understanding of the non-technical vocabulary, and the graphics give added support in this area.

The graphicacy has been aptly chosen to 'teach' vocabulary and concepts and it also follows 'good practice'. This is noted in that the graphics are captioned and the caption is referred to in the accompanying text so that the reader is signalled to refer to the graphic. The graphics are clearly labelled. Furthermore, the graphic is also explained in the accompanying text so that the reader is not left to read a graphic in isolation (see Chapter 4, section 4.2.3.4.).

This facilitates the reading of the text for the science apprentice who is also likely to be reading in a second language. Maximum use has been made of graphics to decrease the cognitive load and to facilitate multi-level learning.

The use of graphics for representations of atoms and molecules is well set out and signalled and the 'abc' of chemistry, 'The Periodic Table of Elements', is well described and labelled. The depiction of the Periodic Table is interesting and clear and referred to by a specific page number in the text.

5.2.2.3. THE ROLE PLAYED BY RHETORICAL STRUCTURING IN LOWERING THE READING LEVEL OF THE TEXTBOOK

The rhetorical structuring in the paragraphing is very effective in lowering the readability level (see Chapter 4, section 4.2.4.).

Each topic heading is generally followed by a topic sentence with each subsequent sentence linking to the next. This is particularly considerate of the second language reader and makes the text more accessible to the reader (see Chapter 2, section 2.2.1.1.). Readers do not have to create structure in the text themselves as they read, and the Working Memory Capacity is

thus freed to retrieve background knowledge, process concepts and store the new knowledge correctly 'linked' to prior knowledge, thus avoiding misconceptions.

The concepts are explained one by one, and it is only once a concept has been well explained and supported by examples that the next concept is introduced.

An effort has been made to situate the concepts within a context and examples are used which activate the reader's background knowledge. Efforts have been made to activate background knowledge and to link new concepts to those already explained.

5.2.2.4. CONCEPTUAL PROGRESSION AND THE READING LEVEL

As noted above, concepts are thoroughly addressed and so strong progression is a characteristic of the book. Concepts follow on each other.

5.2.2.5. GENERAL LAYOUT OF THE TEXTBOOK AND THE EFFECT OF THIS IN LOWERING THE READING LEVEL

- The book has a glossary
- The book has chapter summaries
- The book has chapter assessment exercises
- The book has useful and pedagogically sound appendices

5.2.3. THE READABILITY LEVEL OF THE TEXTBOOK AS A RESULT OF ALIGNMENT TO THE PRESCRIBED CURRICULUM

The book aligns well to the science curriculum prescribed for the grade. The advice given as to the depth in which the content should be expounded, is acted upon. This facilitates the mediation of the textbook by the teacher.

5.2.4. THE TEACHERS' VIEWS ON TEXTUAL READABILITY PROBLEMS

The teachers commented that the glossary is a useful aid in the classroom. However, during the focus-group discussions, they acknowledged the struggle to mediate the textbook in the classroom.

5.2.5. CONCLUSION

In returning to the over-arching research question: 'how readable is the grade 10 chemistry textbook?' it is necessary to integrate both the qualitative and quantitative strands researched.

Thus, while the classical readability formulae place the text at one reading level and sometimes two, above the grade 10 level, the cognitive-structural aspects compensate for this and by giving meaningful support, lower the reading level.

The book is a good teaching and learning resource in that it:

- Takes into consideration the ESL learner
- Supports concepts and vocabulary in a meaningful way
- Is cognitively and structurally sound
- Has a layout conducive to positive support of learning
- The size of the font and the book is comfortable
- The alignment to the curriculum is good

However, once again it must be stressed that mediation of the book in the classroom would enhance the efforts that the authors have made to compensate for the cognitive challenges of reading scientific text. Independent reading of this text would be possible only for expert readers. ESL readers would need to be guided and supported.

5.3. CASE STUDY 3: *SUCCESSFUL PHYSICAL SCIENCE, GRADE 10* 1st Edition (2008)

5.3.1. DISCUSSION OF THE READING LEVEL OF THE TEXTBOOK AS PREDICTED BY THE CLASSIC READABILITY FORMULAE

The three classical formulae used to assess the readability level of this book correlate very closely with each other and predict a readability level of grade 10.

In seeking to understand this correlation (see Chapter 4, section 4.3), some of the data from the semi-structured interview with the editor of the book is of note. According to the editor, the book is prepared with consideration of the needs of ESL readers in mind and the authors themselves teach grade 10 learners who are not native English speakers.

However, as reviewed in Chapter 2 (see section 2.7.), classical and cognitive-structural paradigms work together to give a clearer picture of readability and thus the cognitive-structural aspects of the textbook are now discussed.

5.3.2. DISCUSSION OF THE COGNITIVE-STRUCTURAL READABILITY ASSESSMENTS AND THE READING LEVEL OF THE TEXTBOOK

5.3.2.1. THE ROLE PLAYED BY VOCABULARY IN RAISING THE READING LEVEL OF THE TEXTBOOK

The textbook does not have a glossary and sometimes words are used that have obscure meanings. These are not explained in the context of the text, for example, the use of 'biological realm' and 'textile and furnishing' industry.

Non-technical words are not well supported in the text and yet appear often. This tendency raises the reading level and lowers the comprehension of the text.

On the whole, concept vocabulary is well explained. However there are times when a concept is implicitly referred to, for example the concept of 'impact' (see Chapter 4, section 4.3.1.1.1.); this impairs readability.

5.3.2.2. THE ROLE PLAYED BY GRAPHICACY IN THE READING LEVEL OF THE TEXTBOOK

Graphics are used to some extent to aid readability but better use could have been made of them. Care in making captions simpler would have been helpful (see Chapter 4, section 4.3.2.2.).

The labelling of diagrams depicting the atoms and elements, as well as the presentation of The Periodic Table of Elements, is clear and accessible to the reader, enhancing comprehension of these difficult symbolic areas of chemistry.

5.3.2.3. THE ROLE PLAYED BY RHETORICAL STRUCTURING IN LOWERING THE READING LEVEL OF THE TEXTBOOK

Good use is made of rhetorical structuring. A problem/solution and descriptive rhetorical form is prevalent, with frequent use of listing in bullet form (see Chapter 4, section 4.3.2.3.). However, although the use of bulleting lowers the reading level with respect to classical readability measures, excessive use of this form can cause comprehension difficulty at a deeper level, as the reader learns in 'list' form, not necessarily linking the items logically together.

There is also a tendency to use implicit definitions which is best avoided as it unnecessarily raises the level of reading difficulty.

Continual attempts are made by the authors to activate the readers' background knowledge, as well as to situate the concepts contextually. This enhances comprehension of the written discourse.

5.3.2.4. CONCEPTUAL PROGRESSION AND THE READING LEVEL

Concepts are introduced and well reinforced before another concept is introduced. However, there are times when concepts are used which have not been introduced and often these concepts are above the readers' cognitive level. An example of this is the use of 'impact' and 'spread of impact' with respect to the lining of safety helmets (see Chapter 4, section 4.1.2.1.2.).

5.3.2.5. GENERAL LAYOUT OF THE TEXTBOOK AND ITS EFFECT READING LEVEL

Word boxes and the use of a double page spread layout (where each topic forms a unit spread across two facing pages), aid readability and make the textbook 'user friendly'.

5.3.3. THE READABILITY LEVEL OF THE TEXTBOOK AS A RESULT OF ALIGNMENT TO THE PRESCRIBED CURRICULUM

The textbook aligns very well to the curriculum and efforts have been made not to go beyond the level of the learners. Sometimes, however, in the explanation of everyday examples, more complex concepts are suddenly introduced for which the reader is unprepared.

5.3.4. CONCLUSION

The classical readability formulae measure the book at a grade 10 level but the cognitive-structural aspects of the readability indicate that in some areas the reading level is considerably raised.

The book is an adequate learning and teaching tool and could be improved by:

- The inclusion of a glossary
- Using graphicacy more effectively
- Ensuring that definitions are always explicit

- Taking care that concepts don't just 'arrive' in the text
- Using a larger font
- Having chapter summaries

This discussion of findings now moves on from the textual findings to those regarding the reader and the context.

5.4. THE READER

The reading level of a book as predicted by the reading formulae is calculated with an average reader at that grade level in mind (see Chapter 2, section 2.1.1.). The actual reading level is dependent on the reader: his/her reading ability, language, cognition, previous knowledge, interests and purposes for reading. However, it is clear from the focus-group data analysis (see Chapter 4, section 4.5), the results of national and international tests of South African learners (see Chapter 2, section 2.4.1. and 2.4.2.) as well as the findings of the task team for the review of the implementation of the NCS (see Chapter 2, section 2.4.5.) that:

- **The prior knowledge of the learners is inadequate.** The lack of articulation between the curricula of the FET band and GET has rendered the transition between the two bands difficult for both students and teachers, and this has caused learners to have insufficient background knowledge in the physical sciences to cope with the information load at grade 10 level.
- **The literacy level of the learners is below average.** The language ability of the readers is below the level necessary for them to cope with the grade 10 English reading level of expository science text. The formal language of science evokes a fear of the subject, alienating learners from science and placing it beyond their reach. As a consequence of this, learners struggle to remain motivated.

The results of the assessment of comprehension of non-technical words used in science (see Chapter 4, section 4.4.) reveal that learners' comprehension of these words is disturbingly poor.

5.5. THE CONTEXT

It is important that science texts be well mediated in the classroom and this is the final aspect that affects the readability of texts. Meaningful mediation is a challenge in the classroom and largely difficult because:

- Teachers experience the texts as being complex and above the reading level of their students. This is especially so in the case of ESL learners.
- Outcomes based education has blurred the role of textbooks in the classroom and teachers, although knowing that textbooks are important in the support of content, especially new content, are uncertain as to the extent they may 'lean' on the textbook.
- Teachers have lost faith in the textbooks to assist them in both managing the curriculum as well as being an adequate help in the development of content programs and lesson plans.
- Teachers are not skilled in mediating a text.

5.6. OVERALL SYNTHESIS AND DISCUSSION OF FINDINGS WITH RESPECT TO THE TEXTBOOKS, THE READERS AND THE CONTEXT

Assessing the reading level of the textbooks and matching this to the literacy level of the reader is the first step to ensuring that the LTSM can function optimally. The assessment of the reading level using a combination of the formulae and the qualitative analysis appears to be useful in evaluating the readability of science textbooks.

The formulae are an excellent 'diagnostic tool', as apart from giving the average readability of the textbook, they can also be used to probe the reading levels of the specific KAs. The use of formulae to indicate a reading level in no way suggests that textbooks be 'written to a formula'. Indeed, this would be detrimental, as the very nature of science expository text calls for challenging vocabulary. However, the results from these formulae signal 'danger areas' in the text where special care should be taken to 'lower' the reading level in a manner other than simply stripping the text of 'difficult words' or using short staccato sentences.

Difficult vocabulary must be supported and the recommendations emerging from the cognitive-structural readability research should be applied.

The formulae place the textbooks in this study within a similar range with regard to grade level; the level is well above second language learners' reading level and the findings also reveal that certain science content, for example solution chemistry (see Chapter 4, section 4.1.4.2. and 4.2.4.2.) seems to demand more complex language . The reading level of one section, Chemical Change, was raised in all three textbooks. So it is not within the writers' power merely to simplify the language.

In *Focus on Physical Sciences for Grade 10* , particular care has been taken to compensate for the challenging nature of the language of science by using the cognitive-structural support methods of explicit rhetorical structuring, supportive graphicacy, the glossing of difficult terms, the supporting of non-technical vocabulary, the reduction of both internal and external cognitive load by applying careful sequencing of concepts and the careful introduction of the symbolic language of science. *Successful Physical Science for Grade 10* also applies cognitive-structural measures in an effort to adjust the reading level of the textbook.

However, this qualitative analysis also shows significant differences in the way authors shape the text to the needs of their intended audience.

ESL readers, who comprise the majority of science learners in South Africa, are a 'special needs' audience because they are learning science in a second language, yet it is apparent that the authors do not all seem to have this in mind. The textbook, *Study and Master Physical Sciences for Grade 10* is clearly out of reach for an ESL reader. *Focus on Physical Sciences for Grade 10* and *Successful Physical Sciences for Grade 10* are suitable for ESL readers, provided that the textbook is well mediated by the teacher.

It is clear from the foregoing analysis and discussion that ESL learners are unlikely to be able to use/read the books independently and in the case of one of the books, intense mediation will be necessary, even in a first language English class. This is particularly difficult for teachers who are themselves not first language English speakers.

The writers and editors of the science textbooks may be unaware of the difficulties experienced by the teachers attempting to mediate the textbooks in the classroom. As suggested by Seguin (1989) (see Chapter 2, section 2.4.4.), sufficient time should be allowed for piloting the textbooks in classrooms using a representative sample of students and teachers. This process of intervention is crucial in assuring quality LTSM material.

Teachers often make the final choice of textbook for their students and they need to be equipped with the skills necessary to inform their choices. Criteria should be available to assess the readability of the textbooks.

That textbooks are necessary is a finding that arises from the study. However, unnecessarily difficult textbooks slow down progress through the curriculum, de-motivate and frustrate the learners, making them dependent on their teachers. This does not foster life-long readers and learners.

Greater efficiency in science teaching could be achieved simply by making textbooks more readable. The financial investment in textbooks needs to be justified by the production of quality materials. In an age where sustainability is becoming a life-skill, textbooks need to reflect sound pedagogical practice.

Johnstone (2009) (see Address in Appendix A) notes that valiant efforts in the field of educational chemistry do not seem “to have stemmed the drift of disaffected students out of chemistry” and he attributes this failure to the possibility that science educators have lost sight of the “the principle of beginning where students are and leading them forward” (Johnstone 2009:1). Students need to begin where ‘they are’ (see Chapter 2, section 2.2.5.3.). Failure to take this seriously leads to a mismatch between the reading level of the student and that of the textbook, causing the textbook to fail as an effective LTSM.

5.7. RECOMMENDATIONS ARISING FROM THE STUDY

In this section recommendations are made regarding the

- textbooks,
- the readers of the textbooks, and
- the mediation of the textbooks by the teachers.

5.7.1. RECOMMENDATIONS REGARDING THE TEXTS

It is recommended for scientific expository text that the reading level be brought as close to the reading level of the intended readers as is possible. This can be effectively achieved by using both well researched quantitative diagnostic measures and qualitative remedial methods.

The reading formulae (quantitative measures) are a good diagnostic tool for writers and publishers, signalling areas of raised readability in the texts. Use of these, alerts the authors to the need to use qualitative remedial measures to adjust the reading levels. These include enhancing comprehension with vocabulary support, strong rhetorical structuring and meaningful graphics. The knowledge areas that tend to be more cognitively demanding of the reader require a lower reading level. This can be achieved by taking qualitative measures and decreasing the internal and external cognitive load of the material.

Publishers should consider using the formulae to evaluate the readability of their textbooks during the writing process.

Utmost efforts must be made to support second language readers; nothing regarding the comprehension of the texts should be taken for granted. In the light of the knowledge that the readers are below reading grade level and will be for some time to come, every effort must be made to support concepts and vocabulary in the texts.

It is imperative that more time be given to the piloting of the textbooks in classrooms (especially in ESL classrooms). This would require that the DoE set more realistic deadlines for the development and publication of new LTSMs.

The piloting projects should include training teachers on how to make sound judgments about the readability of textbooks so that they can select appropriate books from the DoE's list of approved textbooks.

The screening of the texts should be more thorough. Those doing the screening should be aware of the reading proficiency of the intended readers. They should also have the skill to judge the readability of the textbooks they are evaluating.

One of the evaluation criteria should relate to the readability of the text. Some distinction should be made as to whether the textbook is intended for readers who are first or second language speakers of English.

THE READER

The gap between GET and FET needs to be narrowed and more attention must be given to the physical science component of the Natural Sciences studied in grade 9. This lack of articulation between the GET and FET is being addressed through the CAPS document but until there is cohesion between the content taught in the two phases, the grade 9 learner will enter grade 10 with a deficit of content knowledge. This severely hampers the readability of grade 10 textbooks.

There should be efforts made to support the development of higher order reading skills required in science, for example, inferential reading. This cannot rest with the science teachers alone but needs to be integrated into the ESL reading programmes.

5.7.2. THE CONTEXT AND MEDIATION

There is a large area for further research in the mediation of text in classrooms since the research has been shown that all three textbooks evaluated in this study require mediation. Teachers in this study admitted having little time for this and being unsure of how to mediate textbooks. Often the fault is not with the textbook but the teacher's understanding of its progressive structuring of concepts and the necessity to work through the activities as

building towards a concept. This suggests that teachers may need to be trained how to use textbooks.

5.8. LIMITATIONS OF THE STUDY

The study was limited as only three of the recommended textbooks could be examined. However these textbooks are a fairly representative sample of those published for grade 10. The textbooks sampled were those used in the three large English medium schools in a Western Cape Region and are indicative of what is found in Western Cape classrooms.

The readers/learners were also only a small sample of the grade 10 learners. However, the sample is again fairly representative of the grade 10 school population.

It was beyond the scope of this study to access the reader and context in which the text is mediated other than through the systemic evaluation results (see Chapter 2, section 2.4.1.) and the focus-group discussions with the teachers.

5.9. CONCLUSION

This study has sought to investigate the readability of the chemistry section of grade 10 science textbooks and the results of the investigation reveal that readability is greatly impaired for a number of reasons.

There is a lack of articulation between the textbook writers/editors and the audience for which they are writing and preparing the texts. This is particularly reflected in the inadequate preparation of the material for the ESL reader. Certain textbooks are completely out of their reach.

This lack of articulation is as a direct result of the DoE not adhering to recommended timeframes needed for the preparation of school textbooks. No time is allocated for the invaluable intervention process of piloting textbooks in the classrooms of their intended audience.

Furthermore, research and development in the training of teachers on the 'best practices' of textbook mediation is critically necessary. This should take the form of programmes developed for pre-service and in-service teacher training.

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APPENDIX A



education

Department of Education
REPUBLIC OF SOUTH AFRICA

**National Curriculum Statement
Grades 10 - 12 (General)**

**Physical Sciences
Content**

June 2006

CONTENTS

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HOW TO USE THIS DOCUMENT

This document gives depth to the Physical Science concepts as outlined in the NCS document. The overview of the Physics component of the Physical Sciences gives guidance on the structure of the Physics curriculum. It shows the flow from concepts to application. and the overview of the Chemistry component gives guidance on the structure of the Chemistry curriculum.

The first column of the core knowledge and concepts section is an extract from the National Curriculum Statement for FET General (Physical Sciences). The second column gives the depth to concepts in the first column. The third column also gives depth to the concepts but these concepts will be examined when the curriculum is fully implemented after 2010. The last column contains commentary, advise and links on how to teach the concepts. The tips in this column are very useful as they help give the teacher insight into how ‘to teach’ and sometimes how ‘not to teach’ the concepts , it also gives guidance on the misconceptions that are inherent in some of these topics.

The practicals are not prescribed in this document, this does not mean that they should not be done. Practical are central to the teaching of concepts in this document. Educators should as much as possible incorporate practicals that help to explain the concepts. Everyday examples about things that learners experience in their surroundings are a best way of explaining the concepts. Teachers can also devise their own practicals.

Overview of the Physics Component of the Physical Sciences NCS

In science teaching it is advisable to use a spiral approach. In a spiral approach, concepts are first introduced in a simple way. Later in the year, or in later years, the concepts are revisited and studied in greater depth. This approach allows learners to gradually build up an understanding of the concepts over a period of time without getting bogged down by too much detail all at once. It also takes into account that learners mature and develop cognitively over time. This means that their ability to cope with greater complexity and cognitive demand also increase.

The Physical Sciences NCS has been designed so that educators can use a spiral approach. In many cases, a concept is introduced in one grade and revisited in later grades. When the concept is first introduced, learners get an opportunity to develop a feel for the concept without going into detail. When the concept is revisited in a later grade, the educator can build on learners' existing understanding, rather than having to introduce the concept from scratch. For example, in Grade 10 learners are introduced to the concept of weight. All they need to learn in Grade 10 is that the Earth exerts a force on any object that tends to pull it towards the Earth. This force is called the object's weight. In Grade 11 learners study forces in detail, both contact and non-contact. They then learn that weight is a special kind of non-contact force. They go on to learn that not only the Earth but all masses exert forces of attraction on each other. They learn how to calculate the magnitude of this type of force using Newton's Law of Universal Gravitation.

The paragraph above illustrates a principle called *conceptual progression*. Conceptual progression is one of two important principles that underlie the design of the NCS. The other principle is *conceptual coherence*. In the past, it was easy to think that Physical Sciences consisted of many unrelated topics. In the Physical Sciences NCS there are many links between topics within each grade (conceptual coherence) and going up from one grade to the next (conceptual progression). It is important to stress these links. When learners are shown the links they will appreciate that Physical Sciences provides a powerful way of understanding the world because it uses only a few basic concepts and principles. These concepts and principles can be applied to a wide variety of contexts. Instead of trying to memorise a great number of facts, learners should be helped to understand and apply fundamental concepts and principles.

In order to promote conceptual progression in the Physics part of the NCS, only three areas of Physics have been selected: Mechanics, Waves, Sound and Light, and Electricity and Magnetism. There is also a strand that integrates Physics and Chemistry, called Matter and Materials. In each of the three Physics strands, concepts are built up over the three years of the FET band. It is thus important to teach the topics assigned to each Grade in the Grade in which they are indicated in the NCS. It is possible, however, to change the order of the strands within each grade.

Big ideas

There are several “big ideas” that thread through all of physics, from school physics all the way up to doctorate level. By identifying these ideas you will help learners to see the unity of physics. One big idea is fields. A field is a region of space in which something experiences a force. A mass experiences a force in a gravitational field; an electric charge experiences a force in an electric field; a moving electric charge and a magnet experience a force in magnetic field. In Grade 10 learners are introduced to all three kinds of field, gravitational, electric and magnetic. In Grade 11 learners study the effects of gravitational field in more detail when they learn about gravitational attraction as a non-contact force. In Grade 11 they also learn more about electric fields, and learn to calculate another kind of non-contact force, the electrostatic force between charges. In Grade 11 and 12 they learn about the relationship between electric and magnetic fields.

Another big idea is boundary conditions. There are many instances when something travels from one medium into another medium. The place where the two media meet is called the boundary. Boundary conditions determine what happens when a boundary is reached. Boundary conditions are very important in the study of any kind of waves, whether they be transverse or longitudinal, waves on a string or electromagnetic waves. In general, whenever a wave reaches a boundary between two media, part of the wave will be reflected and part will be transmitted. This behaviour of a wave is what makes it possible to form ultrasound images of a foetus inside its mother. The speed of the wave will change when it passes from one medium to another. That is why light bends, or refracts, when it meets a boundary between two media, such as air and glass. In Grade 10 learners study boundary conditions for a pulse on a spring, standing waves and light passing from one medium to another. In Grade 11 they study the effects of boundary conditions when they learn about ultrasound and again when they study standing waves in different kinds of instruments. In Grade 12 they learn about the effects of boundary conditions on electromagnetic waves when they study signal tuning in electronics.

A third big idea is superposition. Superposition is the addition of two or more effects at the same point. In Grade 10 learners are first introduced to superposition when they study what happens when two pulses on a spring reach the same point at the same time. Later they explore standing waves, which result when two waves of specific frequencies superpose. In Grade 11 they learn about superposition of forces and of electric fields. In Matter and Materials they also learn about superposition of energy levels in solids.

Mathematical tools

Physics makes use of various mathematical tools. One of the most widely used mathematical tools is algebra. In the FET band, learners need to be able to solve an equation containing one unknown. Wherever possible, they should first rearrange the equation to make the unknown the subject of the equation, and then substitute the given numerical values into the equation. Another mathematical tool is trigonometry. Learners need to know how to calculate the basic trigonometric functions of sine, cosine and tangent for any angle, and how to find the angle given its sine, cosine or tangent. They also need to know how to use Pythagoras’s Theorem. The third mathematical tool needed is vectors. Learners need to know how to add and subtract parallel vectors, how to calculate the components of a vector and to determine the resultant vector given its components.

Quantities used in physics calculations must be in SI units (Système Internationale d'Unités). In many cases, the quantities in a problem are given in other units, e.g. nm or km, because the SI unit is too big or too small to be convenient. In these situations, learners must convert all quantities to SI units before substituting them into equations.

Representations

Physics uses a number of different representations. Some representations are used in many different contexts, such as graphs and equations. Other representations are only used in a particular area. In the NCS we use several specific representations. Light rays, which are lines with arrows in them, are used to represent the path that light travels. They are very useful for showing how the path changes when light reflects or refracts. Electric and magnetic field lines are used to show the shape and direction of the electric and magnetic fields, respectively. They also indicate where the field is larger or smaller according to whether they are more closely spaced or further apart. Circuit diagrams are used to indicate the electrical connections in an electric circuit. Circuit diagrams do not, however, represent the physical layout of a circuit.

Conceptual pathways and links

Mechanics

In Grade 10 learners are introduced to several concepts that are fundamental to mechanics: position, displacement, velocity and acceleration. It is very important to lay the foundation for future learning by making sure that learners have a correct understanding of each of these concepts. The concept of reference point is needed right at the beginning because position must always be measured relative to something. Frame of reference can then be defined as a reference point combined with a set of directions. A frame of reference can be represented by a set of coordinate axes. In that case, the reference point is the origin. Once the position of an object is defined relative to a reference point, the displacement of the object is defined as its change in position (final minus initial). Displacement has magnitude and direction and is therefore a vector. In order to stress the fact that displacement is the *change* in position, it is useful to represent position by x (or y) and displacement by Δx (or Δy). Displacement depends only on initial and final position, not on the path travelled. Distance is how far an object travels along a particular path. It does not have a direction, so it is a scalar.

Velocity is the rate of change of *position*, which is the same as the displacement (not change in displacement) divided by the time taken. Velocity is also a vector. Speed is the magnitude of velocity, so it is a scalar. In order to distinguish between an instant in time and the time taken or time interval, it is useful to represent an instant by t and time taken by Δt . Then velocity can be expressed as

$$v = \frac{\Delta x}{\Delta t}$$

Instantaneous velocity is the velocity of an object at one instant. Average velocity is the velocity an object would have if it covered a certain displacement in a certain time interval and travelled at the same speed the whole time.

Acceleration is the rate of change of velocity. Mathematically, it can be expressed as:

$$a = \frac{\Delta v}{\Delta t}$$

Acceleration is also a vector. Acceleration does not provide any information about a motion, but only about how the motion changes. It is not possible to tell how fast an object is moving or in which direction from the acceleration.

After learning the definitions, learners need to learn how to draw graphs of position versus time, velocity versus time and acceleration versus time. They also need to know how to translate from one kind of graph to another, how to explain the motion represented by a graph using words, and how to sketch any of the three kinds of graphs given a description of a motion in words. Given a position versus time graph, the velocity versus time graph can be obtained by taking the gradient. If the graph is a curve then to find the velocity at one instant, draw a tangent to the curve at that point and take the gradient of the tangent line. Given a velocity versus time graph the acceleration versus time graph can be obtained by taking the gradient. The displacement can be obtained from a velocity versus time graph by calculating the area under the curve.

In Grade 10 learners also learn how to use the equations of motion (kinematics equations) to solve problems involving motion in one-dimension. They then apply these *same* equations (they should not derive new equations) to freefall, i.e. situations where the acceleration is the acceleration due to gravity, g . In Grade 12 learners revisit the equations of motion and freefall when they study projectile motion. They also revisit frames of reference when they study situations involving relative motion.

In Grade 10 learners are introduced to gravitational potential energy, kinetic energy and conservation of energy. In Grade 12 they revisit these concepts when they learn about the work done by a force, which causes the kinetic energy of an object or system to change.

In Grade 10 learners are introduced to weight, a special kind of force. In Grade 11 they study different kinds of forces, both contact and non-contact. They learn about the forces between any two masses, which can be calculated using Newton's Law of Universal Gravitation. They apply the concept of gravitational field, which they first met in Grade 10, to explain how objects can exert forces on each other without touching. They study Newton's First, Second and Third Laws of Motion, which explain the relationship between force and motion. In Grade 10, when learners study kinematics they only consider a motion and not what causes it. In Grade 11 they learn that any *change* in motion is caused by a net (unbalanced) force. Learners are introduced to momentum in one dimension, and learn that a net force causes an object's momentum to change. The change in momentum is equal to the impulse delivered by the force, which is the product of the force applied and the time for which it is applied. In Grade 12 learners revisit momentum when they study situations involving momentum in two dimensions, including elastic and inelastic collisions.

Waves, sound and light

In Grade 10 learners start this strand by studying the motion of a single pulse, before going on to learn about waves. A pulse is a single disturbance that travels through a medium. A wave is a periodic, continuous disturbance. A pulse has pulse length and amplitude. A wave has wavelength, amplitude, period and frequency. In Grade 11 learners see how these different characteristics of a sound wave relate to the features of sounds we hear, such as pitch and loudness.

When the particles of a medium move at right angles to a wave, the wave is called transverse; when the particles of the medium move parallel to a wave, the wave is called longitudinal. For either type of wave, there is no net displacement of the particles (they return to their equilibrium position), but there is a net displacement of the wave. There are thus two different motions: the motion of the particles of the medium and the motion of the wave.

The motion of a single pulse travelling along a string or spring provides an excellent opportunity for learners to apply and extend what they learn in mechanics about motion graphs to a new context. A drawing of a single, transverse pulse overlaid with a set of x-y axes is like taking a snapshot of the string at one instant. Using this y vs x graph, learners can then draw graphs of y vs t and v_y vs t for a single particle of the string and x vs t and v_x vs t for a point of the pulse shape (e.g. the peak). These graphs are easier to draw if an ideal pulse is drawn that is straight-sided, rather than curved. It is also useful to draw a pulse that is asymmetrical as it shows the difference between the shape of the y vs x and y vs t graphs. In Grade 11 learners draw motion graphs for particles of the medium and a point on the wave for longitudinal waves.

Grade 10 is the first time learners encounter boundary conditions, one of the big ideas in the NCS. They should be given opportunities to see that when a pulse reflects from a fixed end it inverts and from a free end it does not invert. These experiments can all be done using long springs that are not too stiff.

In Grade 10 learners see that when a pulse encounters another medium, part of it is reflected and part of it is transmitted. The behaviour of waves at a boundary is revisited in Grade 11 when learners study ultrasound, which makes use of the fact that part of a wave is reflected and part is transmitted at every boundary between two media in order to form images inside the human body.

Another effect of a change in medium on a wave is that the speed of the wave changes. Learners can observe the change in pulse speed using springs. They can then apply this same concept to the refraction, or bending, of light, which is caused when light waves change speed in going from one medium to another. The degree of bending is indicated by the refractive index of a material, which is the ratio of the speed of light in vacuum to its speed in the material. The angles of incidence and refraction when light travels from one medium to another can be calculated using Snell's Law. The bending of light when it changes medium has many useful applications in devices that use lenses, such as eyeglasses, microscopes and telescopes, which learners study in Grade 11. South Africa has the largest optical telescope in the world, called SALT, which is in Sutherland in the Northern Cape.

In Grade 12 learners learn that not only light but also matter can sometimes act like a wave. In that case, it has a wavelength associated with it, called the de Broglie wavelength. Learners find out that very sensitive microscopes use electrons rather than light to observe tiny objects. Conversely, in Matter and Materials in Grade 12 they learn that light sometimes behaves like a particle when they study the photoelectric effect. It is important to remember that the particle model and wave model of light are just models, each of which describes some aspects of the behaviour of light. Light is not a wave or a particle—it is a form of energy.

In Grade 10 learners also study reflection of light. When light reflects from a very smooth surface, such as a plane mirror, a clear image is formed. This is called specular reflection. When light reflects off an uneven surface, such as a wall, the surface is illuminated but no image is formed. This is called diffuse reflection. Diffuse reflection enables us to see all objects that are not sources of light. We cannot see an object unless light from that object enters our eyes. Light rays are lines with arrows drawn on them that are used to represent the path of light. Learners also study total internal reflection, which occurs when light strikes the boundary between a material with bigger refractive index and one with smaller refractive index. Total internal reflection has many important applications, including fibre optic cables used for communication and endoscopes used to see inside the human body.

Learners are also introduced to another big idea in Grade 10, superposition. They should have the chance to observe the superposition of pulses on the same side and on opposite sides of a spring. They should then observe standing waves, which also involve superposition. Learners then study the effect on the frequency of standing waves of different boundary conditions, which cause there to be either a node or an antinode at the boundary. They revisit standing waves in Grade 11 when they learn about the physics of music, and how different instruments produce different kinds of waves and therefore different sounds. They revisit superposition when they study interference in Grade 12.

In Grade 12 learners can link their knowledge of reference frames to waves when they learn about the Doppler effect, which is a shift in wave frequency that occurs when either the wave source or receiver is moving. The Doppler effect has important applications, such as being able to tell the heart rate of a foetus in the womb, and to work out how far away distant stars are by measuring how much their emission spectra are shifted relative to stars that are close by. The latter application links to emission spectra in Grade 12 Matter and Materials.

In Grade 12 learners also study colour, which has many important applications in painting, printing, photography and television. They learn about the relationship between colour and wavelength and frequency, which links to the section on the electromagnetic spectrum in Grade 12 Electricity and Magnetism. They study additive primary colours (red, green and blue), which are relevant to how the eye and a television work, and subtractive primary colours, magenta, yellow and cyan, which are relevant to pigments, paints and printing.

Electricity and Magnetism

In Grade 10 learners study permanent magnets and are introduced to a third type of field, a magnetic field. They learn that it is not possible to isolate one magnetic pole—magnetic poles always come in pairs, called north and south. As for electric charges, like magnetic poles repel and opposite magnetic poles attract. The magnetic field can also be represented by field lines, which point from the North Pole to the south pole of a magnet. The magnet field of a permanent magnet can be explained in terms of domains. All objects have moving electrons with associated magnetic fields. In most materials these fields point randomly in all directions and so cancel out. In some materials, called ferromagnetic, there are regions called domains where the magnetic fields due to a number of electrons line up. In permanent magnets, many of the domains line up, creating a net magnetic field. In Grade 11 learners learn about various interactions between charges and magnetic fields. They learn that every electric current has an associated magnetic field. A changing magnetic field induces an emf in a circuit, which can be calculated using Faraday's Law. A charge that moves in a magnetic field experiences a force due to the field. These phenomena have important applications in everyday life, such as transformers and televisions. In Grade 12 the relationship between induced emf and changing magnetic field is used to explain how motors and generators work.

In all situations involving magnetic fields and moving charges, only the Right hand Rule is used to find directions. This is done to reduce confusion amongst learners who may struggle trying to remember which hand and which fingers to use if there is more than one rule. It is also good preparation for learners who will study Physics after they leave school, since the same method is used to find vector cross products.

In Grade 10 learners are introduced to electric charges. They learn that there are two types of electric charge, which are called positive and negative because when they are brought together they cancel out, resulting in an object that is neutral. Neutral objects still contain positive and negative charges, but in equal numbers, while charged objects have extra charges. Learners again encounter the concept of field when they learn that an electric field is a region of space in which a charge experiences a force. Unlike a mass in a gravitational field that always experiences a force of attraction, a charge in an electric field can experience an attractive or a repulsive force. Simple experiments can be

performed to show that like charges repel and opposite charges attract. A charged object can also attract an uncharged object when the molecules in the uncharged object are polarised (have one side more positive and one side more negative); although the object as a whole remains neutral, the molecules may rotate so that one side of the object becomes more positive and the other side more negative.

In Grade 10 qualitative experiments can be done to show that the magnitude of the force between charges increases as the size of the charges increases or the distance between them decreases. In Grade 11 learners learn how to calculate the magnitude of the force between charges when they study Coulomb's Law. The equation representing Coulomb's Law has the same form as the equation representing Newton's Law of Universal Gravitation, which learners encounter in Grade 11 Mechanics. Both equations represent the forces exerted by two objects on one another that interact by means of a field. In both cases the forces are proportional to the product of a property of the two objects (mass or charge) and inversely proportional to the square of the distance between them. In both cases, the forces due to a number of objects can be superposed. In Grade 11 learners also learn how to calculate the electric field due to a charge, and how to superpose the electric fields due to a number of charges in order to find the resultant electric field at a given point. They represent the electric field at various points by drawing electric field lines that indicate the direction in which a positive test charge would move if it were placed at each of those points. Larger electric fields are represented by field lines that are closer together. Learners then calculate the electrical potential energy due to a number of charges. As with gravitational potential energy for a mass, the electrical potential energy of a charge is the energy it has because of its position relative to objects it interacts with. Electric potential is then defined as the electrical potential energy per unit charge.

In Grade 10 learners get a qualitative introduction to electric circuits. They learn that there must be a closed circuit for charges to flow, and that the rate of flow of charge is called the current. Which circuit elements are placed in the circuit and in which arrangement determines the resistance of the circuit, which can be thought of as the obstacle to the flow of charge. In order for charges to flow in a circuit there must be a difference in electrical potential energy across the circuit. A battery is a device that provides potential difference, which is the difference in electrical potential energy per unit charge, also called voltage. The voltage across the battery when it is not in a circuit is called its emf. (Note that in the past the word "battery" was used to mean a combination of cells; nowadays the word "battery" is used in physics, regardless of how many cells there are and "cell" is seldom used.) Learners learn that the voltage across a circuit element is proportional to its resistance, and the current through it is inversely proportional to its resistance, but they do not do detailed calculations. They learn that, in general, the current that flows through a battery depends on how many resistors there are in a circuit and how they are arranged. More resistors in series create a greater obstacle to flow so there is less current; more resistors in parallel create more pathways for the flow of charge so there is more current. Learner also learn how to measure the voltage across a circuit element and the current through it using a voltmeter and an ammeter, respectively. In Grade 11 learners study Ohm's Law, and use it to solve problems involving the resistance, voltage and current of circuits of different configurations. They learn how to calculate the equivalent resistance for parallel and series circuits. They also learn about series-parallel circuits, which are neither purely series nor purely parallel. They study the Wheatstone Bridge as an important example of another type of circuit, namely a bridge circuit.

In Grade 12 learners study alternating current (AC). AC is the form in which electrical energy is generated and supplied by the national grid. It allows power stations to generate very electric power at large voltages, which can be transmitted at low current along the power lines without losing too much energy as heat. Transformers in substations step down the voltage so that buildings such as homes, offices, schools and factories are supplied with a lower voltage that is not so dangerous. In Grade 11 learners are introduced to capacitors as devices for storing charge. In Grade 12 learners see how capacitors can have a variety of uses in AC circuits, such as for filtering out certain frequencies. They are also introduced to inductors, which can be used to regulate the current in an AC circuit. When circuits contain resistors (R), capacitors (C) and inductors (L), instead of resistance learners must calculate the impedance of a circuit. By changing the impedance of an LRC circuit, it can be used as a tuning circuit, such as in a radio.

In Grade 12 learners learn about diodes, including light-emitting diodes (LEDs), which are widely used in daily life, e.g. in digital clocks and remotes for television sets, cars and gate motors. This builds on what they learnt in Grade 11 Matter and Materials when they learnt about electronic properties of matter.

In Grade 12 learners study electromagnetic (EM) radiation. EM radiation consists of electric and magnetic fields that oscillate at right angles to one another. In some cases, the behaviour of EM radiation can best be described using a wave model, in which case it has a wavelength and frequency. In other cases, its behaviour is best described by thinking of it as a collection of particles, called photons, which have a discrete amount of energy. It is important to understand that EM radiation is a form of energy, and that wave and particle models provide different tools for describing various aspects of its behaviour. In Grade 12 Matter and Materials learners study the photoelectric effect, where the particle model is appropriate for describing the behaviour of EM radiation. In Grade 10, 11 and 12 Waves, Sound and Light, learners have studied light, which is one form of electromagnetic radiation, corresponding to a narrow range of frequencies. In Grade 12 they learn that there are other forms of EM radiation, with higher and lower frequencies than light, such as microwaves and X-rays. They study various applications of different parts of the electromagnetic spectrum.

Overview of the Chemistry component of the Physical Sciences NCS

The chemistry content in the new NCS appears in three KAs (Knowledge Areas): Chemical change, Chemical systems, and Matter and Materials. The last of these is described as an integrated KA, but nevertheless it needs to be taken into account in the commentary.

Chemistry has often been called the “central science” because in several ways it lies between physics (on the one hand) and biology and geology (on the other hand). This centrality is increasingly evident today, as chemistry has thoroughly permeated the life sciences and the medical sciences. Today, chemistry news magazines are dominated by chemical developments in areas traditionally regarded as separate, for example, biology.

The reason that chemistry has “invaded” these other sciences (or has been adopted by them) is that molecular level knowledge is now so deep and so wide. This has meant that areas of science previously considered too complicated to study at the molecular level, are no longer so-regarded. Human biology, medical diagnosis and treatment, agriculture, global climate change, and new materials for demanding applications in IT, aerospace, low-cost housing, are all benefiting from this powerful new knowledge. Even molecular gastronomy is flourishing (especially in France). Truly, molecular design has come of age.

In view of this “molecular power”, it is perhaps unsurprising to discover that almost every object we touch today is, or contains, a product of chemical industry. South Africa has a relatively strong chemical industry in relation to the size of its manufacturing sector. This is very largely based upon South Africa’s own natural resources, which are substantial. South African scientists and engineers have a lot to their credit. We need to attract learners to the field for careers in maintaining, controlling, developing and leading the industry. Understanding its crucial role is a first step to achieving this.

Several things follow from this assessment of chemistry today. Chemistry is a critically important science for the future of the country. However we need to recognize that its character today is very different from what it was, when most of us learned chemistry. Things regarded as important even 25 years ago, may not be any more. They may still be true, but there are more important things now. Similarly some of the language and terminology of the past is rarely used any more. Often it was linked with outmoded models and theories, and to maintain it today only confuses.

A number of respected science educators have drawn attention to the difficulty for beginners in managing, all at the same time, the macro-level, the micro-level, and the symbolic-level descriptions of chemical phenomena. It is indeed inherently difficult to think and comprehend in three ways, all more or less at the same time. Many chemistry teachers compound the problem by confusing dialogue and by avoiding the issue. The fact is that the “molecular power” referred to above demands the ability to handle this problem. Learners today really need to be inducted into this new arena; it cannot be ignored. Hence a continuing attention to this throughout the FET phase is a core requirement.

The content of the chemistry part of the NCS is a sound attempt to reflect all the above. The statements are on the whole not very detailed. This provides “space” for educators to make choices, especially for example in relation to their own knowledge and the circumstances (physical, environmental) in which they teach. National policy expects that educators will design their own curricula; for this to be realized they must have some space. The chemistry statements therefore provide guidelines or a framework.

All aspects of atomic and molecular structure are introduced in Matter and Materials. Also to be found in this KA, are all aspects of the relation between atomic and molecular characteristics and the “static” properties of substances and materials. By static is meant properties other than chemical reaction. This suits the situation that this KA is an integrated one of physics and chemistry emphases. Physics has no interest in chemical reaction. Chemists and physicists work together on materials science and technology. In this KA we therefore find the basics of the structure of the atom and chemical bonding. At grade 10 level these matters are related with rather simple bulk properties – mostly rather traditional. At grade 11 level they are related to electronic properties in the solid state. This is new ground at school level, but so clearly needed today. At grade 12 level they are related to structure and function in organic molecules and especially to macromolecules. Again, this is new ground at school level, but so right for our times.

The KA Chemical Change deals of course with exactly that. In particular its emphasis is on the basic ideas associated with this part of chemistry. In grade 10 the crucial distinction between physical and chemical change is a principal feature. The molecular understanding of this distinction and the use of balanced chemical equations, provide an opportunity to develop the ability to work with the three levels of description. It is implied that the treatment at grade 10 is mostly qualitative, but at grade 11 level it becomes clearly more quantitative. This is traditionally seen as difficult and of course it is right there that the macro-, micro- and symbolic are fused into one big problem-solving nightmare. It may be argued that giving consistent attention to this trio of descriptions right from the start of grade 10, should help. The more practice one gets the easier it becomes! And more practice is again available in the “Energy and chemical change” and “Types of reaction” components at grade 11. The KA concludes in grade 12 with major time being devoted to rate and equilibrium and to electrochemical reactions. These allow for some quantitative follow-up on the acid/base equilibrium ideas, the rates (activation energy) ideas and redox ideas that will have been introduced qualitatively in grade 11. Tracing the evolution of different chemical change concepts through grades 10-12, the progression is consistently from qualitative to quantitative aspects.

Chemical systems is a new invention. Its title and content lend themselves to exploring some of the broad landscape now occupied by chemistry. It aims to take chemistry out of the test tube and the school classroom and to provide a chance to taste a bit of the real action. The test tube was simple; the environment is not. But that is what we live with and what we really need to learn about. It is a chemical system. This KA works with the other two, already discussed, providing for rich exemplification and application, either before or after theoretical ideas have been introduced. In other words, as the NCS document states, the educator can choose the sequence as well as the details of the content. Some educators have been conditioned to believe that first you do the theory and then the applications. That sequence is however negotiable in the way this KA is constructed. In grade 10, and subsequently in grade 11, a truly global perspective is adopted. In grade 10, the great global cycles, driven by the sun, and the immense hydrosphere, are a wonderfully vital and open canvas for today’s learners to study. The atmosphere (and its problems) and the lithosphere (and its exploitation), continue in the same style, providing opportunities for

applying (and reinforcing) basic chemical knowledge at all three levels. A meaningful understanding of our environment and what we do to it, leads naturally to an understanding of what we should not be doing to it. The media give much attention to ‘the environment’, and much is unscientific and emotive. Today’s learners need to be scientifically informed about these popular words and phrases – global warming, greenhouse gases, etc. Educators in the physical sciences carry a great responsibility to achieve this. In grade 12 the global perspective is extended to chemical industry. Following naturally from a basic knowledge of the nature of the environment and the resources it offers, we can try to comprehend the nature and impact of the all-pervasive chemical industry. No other science has an industry to call its own, and it is a remarkable human achievement. The human population of our time would be decimated, and society as we know it would be crippled and destroyed without this industry providing in different ways for our food, our clothing, our housing and our transport. There is a wide-open opportunity here to apply and reinforce all the basic ideas that may previously have been covered, or else to proceed on a need to know basis, developing new concepts as required. A grade 12 educator may choose to leave this KA till last, or put it first and let the necessary concepts of rate and equilibrium and electrochemistry and macromolecules be confronted when they must.

The chemistry component of the NCS offers a chance to overcome the traditional 25 or more years gap between school chemistry and chemistry. The question is raised “how far must teachers go in teaching topics in the new curriculum?” A rather strange question in the OBE context, I think. Whatever the answers might be, the aim should be to allow learners to see and comprehend where we are and where we are going in three ways: macro-, micro- and symbolic.

Core knowledge and concepts (Learning Outcome 2 - Grade 10)

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Constructing and Applying Scientific Knowledge

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MECHANICS 12,5%			
<u>Motion in one dimension:</u>	Learners must be able to:	Learners must be able to:	
<ul style="list-style-type: none"> • Position, displacement, distance; 	<ul style="list-style-type: none"> • Define position relative to a reference point; position can be positive or negative. • Define displacement as a change in position. It has both magnitude and direction and is therefore a vector. • Distinguish between displacement (change in position with respect to a reference point) and distance • Convert between different units of distance and displacement, e.g. m, km, cm. 		<p>The concepts of position and reference point have been largely ignored or glossed over in the previous SA syllabus. They are crucial in forming the foundation of all kinematics.</p> <p>Use the symbol x (or y) for position and Δx (or Δy) for displacement to emphasise that displacement is a change in position. Use d for distance.</p> <p>Displacement is independent of path taken, while distance depends on the path. Displacement can be positive or negative; distance is always positive. An object that moves away from its starting point and then comes back to the same point has zero displacement but travels a non-zero distance. Displacement is a vector; distance is a scalar.</p>
<ul style="list-style-type: none"> • Speed, average velocity, instantaneous velocity; 	<ul style="list-style-type: none"> • Define instantaneous velocity as the rate of change of position. Velocity has magnitude and direction so it is a vector. • Explain what positive and negative values of velocity mean. • Define average velocity as the displacement for the whole motion divided by the time taken for the 		<p>Mathematically velocity is defined as</p> $v = \frac{\Delta x}{\Delta t}$ <p>Use t to represent an instant and Δt to represent a time interval. Learners have trouble differentiating between a quantity and the change in a quantity,</p>

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	<p>whole motion.</p> <ul style="list-style-type: none"> Define speed as the magnitude of velocity. Speed is a scalar. Distinguish between speed and velocity Distinguish between average and instantaneous speed and velocity. Calculate average speed and velocity and express answer in suitable units. Convert between different units of speed and velocity, e.g. $\text{m}\cdot\text{s}^{-1}$, $\text{km}\cdot\text{h}^{-1}$. 		<p>so the distinction must be made from the beginning.</p> <p>Note that the symbol separating compound units is a multiplication dot, not a full stop.</p>
<ul style="list-style-type: none"> Acceleration; 	<ul style="list-style-type: none"> Define acceleration as the rate of change of velocity. Acceleration is a vector. Explain what positive and negative values of acceleration mean. Understand that acceleration provides no information about the direction of motion; it only indicates how the motion (velocity) changes. Give an example of constant acceleration 		<p><u>Mathematically acceleration is defined as</u> $a = \frac{\Delta v}{\Delta t}$</p>
<ul style="list-style-type: none"> Description of motion in words, diagrams, graphs and equations; 	<ul style="list-style-type: none"> Use positive and negative signs to denote direction of displacement, velocity and acceleration. Describe in words and distinguish between motion at constant velocity (uniform) and constantly accelerated motion. Describe the motion of an object given a position vs time, velocity vs time or acceleration vs time graph 		<p>The emphasis should be on concept formation and testing understanding and not on esoteric applications that force teachers to spend weeks drilling and practicing answers to application questions.</p> <p>A description of the motion represented by a graph should include, where possible, an indication of whether the object is moving in the positive or negative direction, speeding</p>

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	<ul style="list-style-type: none"> • Given a description of a motion in words, sketch graphs of position vs time, velocity vs time and acceleration vs time • Given one of three motion graphs, i.e. x vs t, v vs t, or a vs t, sketch the other two graphs. • Determine the velocity of an object from the gradient of the position vs time graph. • Determine the acceleration of an object from the gradient of the velocity vs time graph. • Determine the displacement of an object by finding the area under a velocity vs time graph. • Use the kinematics equations to solve problems involving motion in one dimension. <p>Demonstrate an understanding of motion of a vehicle and safety issues, such as the relationship between speed and stopping distance</p>		<p>up, slowing down, moving at a constant speed (uniform motion) or remaining at rest. The three graphs are very different representations of a motion.</p> <p>Learners need to reason both from graphs to words and from words to graphs.</p> <p>For example reference to using area under a velocity time curve need not be difficult and examples can be made concrete if calculating displacement is confined to adding up squares (the area of a square represents displacement; a car traveling at 20 m s^{-1} for 3 s travels 60 m. – the addition of three squares of dimensions $20 \text{ m} \cdot \text{s}^{-1}$ by 1 s).</p> <p>Reduce the number of symbols used. It is easiest to use v_i for initial velocity, v_f for final velocity, Δx for displacement and Δt for time taken.</p> <p>Symbols v and u are also used to show final and initial velocity respectively</p> <p>Problem-solving strategies should be taught explicitly. Problem solutions should include a sketch of the physical situation, including an arrow to indicate which direction is chosen as</p>

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			positive. Physical understanding should be stressed above mathematical manipulations.
<ul style="list-style-type: none"> • Frames of reference. 	<ul style="list-style-type: none"> • Describe the concept of a frame of reference by, for example, describing the different view a person in a moving train and a person alongside the railway track has of the same ball being thrown vertically upward and then caught by person in the train • Explain that a frame of reference has a zero point, or origin, and a set of directions, e.g. right and left, or up and down. It can be represented using a set of coordinate axes. 		Frames of reference will be covered in more detail in grade 12. Do not do relative motion problems in Grade 10. Just introduce the concept and motivate for why it is important.
<u>Gravity and mechanical energy:</u>			
<ul style="list-style-type: none"> • Weight (force exerted by the earth on an object); 	<p>Describe weight as the gravitational force the Earth exerts on any object.</p> <p>Calculate weight using the expression mg, where g is the acceleration due to gravity. Near the earth the value is approximately $9,8 \text{ m}\cdot\text{s}^{-2}$.</p> <p>Calculate the weight of an object on other planets with different values of gravitational acceleration.</p> <p>Distinguish between mass and weight.</p>		<p>This is just an introduction to weight. Wait until Grade 11 to introduce Newton's Law of Universal Gravitation.</p> <p>Stress that weight is a force and mass is a measure of how many molecules there are in an object. Weight is measured in newtons, mass in kilograms. The weight of an object is different on different planets, but the mass is the same.</p>
<ul style="list-style-type: none"> • Acceleration due to gravity (acceleration resulting from the 	<ul style="list-style-type: none"> • Define gravitational field as a region of space in which a mass experiences 		Introduce the concept of field as a region of space in which an object

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force exerted by the earth);	<p>a gravitational force.</p> <ul style="list-style-type: none"> Define free fall, i.e. motion (up or down) in the earth's gravitational field when no other forces act Use a diagram of a multi-exposure photograph (supplied or self generated) of a falling object to explain that an object in free fall accelerates (e.g. the distance per time interval increases at a constant rate) Give the approximate value of the acceleration due to gravity ($g = 9,8 \text{ m}\cdot\text{s}^{-2}$) ignoring air friction Use the equations of motion to solve 1-D kinematics problems for objects in freefall 		<p>experiences a force. In the case of a gravitational field, the force is a gravitational force. Later in the year, make a link with electric field (where an electric charge experiences a force) and magnetic field (where a moving electric charge experiences a force). Field is one of the "big ideas" that threads through all of physics. The value of the gravitational acceleration, g, is the same as the value of the gravitational field.</p> <p>Learners should realise that freefall motion is just a special case of motion with constant acceleration. Do not derive a new set of kinematics equations. Use the same equations as before, but make the value of acceleration equal to g. It is important to select either up or down as the positive direction in each problem and then check that the signs are correct for all quantities involved.</p>
• Gravitational potential energy;	<ul style="list-style-type: none"> Define potential energy of an object as the energy it has because of its position relative to objects it interacts with Determine the potential energy of an object using $U = mgh$ or $PE = mgh$ Give the relationship between potential energy of an object and its 		<p>Energy is another big idea. In the past, the syllabus referred to many kinds of energy. Fundamentally, there are only two kinds of energy – potential and kinetic (excluding rest mass energy).</p> <p>However, there are many kinds of potential energy. Introduce gravitational potential energy as the</p>

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	<ul style="list-style-type: none"> ○ mass and ○ height above a reference point 		energy of a mass due to its position above the earth (the object it interacts with). Later on, make a link to electrical potential energy (the energy of a charge due to its position relative to other charges it interacts with).
<ul style="list-style-type: none"> • Kinetic energy; 	<ul style="list-style-type: none"> • Grade 12 • Determine the kinetic energy of an object using $KE = \frac{1}{2}mv^2$ • Give the relationship between kinetic energy of an object and its <ul style="list-style-type: none"> ○ mass and ○ velocity 		Introduce kinetic energy as the energy an object has because of its motion.
<ul style="list-style-type: none"> • Mechanical energy (sum of gravitational potential energy and kinetic energy); 	Define mechanical energy as the sum of the potential and kinetic energy		
<ul style="list-style-type: none"> • Conservation of mechanical energy (in the absence of dissipative forces). 	<ul style="list-style-type: none"> • State the law of the conservation of energy • State that ignoring factors like air resistance, the mechanical energy of an object moving in the earth's gravitational field (or accelerating as a result of gravity) is constant (conserved) • Use the conservation of mechanical energy to show that the velocity of a body in free fall is independent of its mass • Use conservation of mechanical energy to carry out calculations on bodies accelerating due to gravity e.g. object dropped or thrown vertically upwards and the motion of a 		<p>Conservation of mechanical energy implies that the total amount of mechanical energy in a system remains constant. That means that energy is transformed from kinetic to potential or vice versa.</p> <p>In conservation of energy problems, the path taken by the object can be ignored. The only relevant quantities are the object's velocity and height above the reference point.</p>

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	pendulum bob, roller coaster, and so on, where friction is ignored.		
WAVES, SOUND AND LIGHT 12,5%			
<u>Transverse pulses on a string or spring:</u>			
<ul style="list-style-type: none"> • Pulse length, amplitude, speed; 	<ul style="list-style-type: none"> • Define a pulse. • Identify the pulse length and amplitude on a drawing of a transverse pulse. • Given the distance traveled and time to travel, calculate the pulse speed 		<p>Sometimes learners are taught about waves without ever learning about pulses. A pulse is a single disturbance. It has an amplitude and pulse length, but no frequency, since it only happens once.</p> <p>Try to let learners observe the motion of a single pulse travelling along a long, soft spring or a heavy rope.</p>
<ul style="list-style-type: none"> • Graphs of particle and pulse position, and velocity,; 	<ul style="list-style-type: none"> • Describe in words the motion of a particle of the string or spring and of the pulse itself and explain how these two motions are different. • Draw graphs of transverse position and velocity versus time, y vs t and v_y vs t, for a particle of a string or spring as a pulse move past it. • Draw graphs of horizontal position and velocity versus time, x vs t and v_x vs t, for a particular point on the pulse itself. 		<p>Stress the fact that there are two different motions—the motion of the particles of the medium and the motion of the pulse. These two motions are at right angles to each other when the pulse is transverse.</p> <p>Link to motion graphs in mechanics. Now there is a position vs time and velocity vs time graph for a particle of the medium (in the y direction) and a position vs time and velocity vs time graph (x direction) for a point on the pulse. Just as in mechanics, learners can obtain the velocity vs time graph by taking the gradient of the position vs time graph.</p>

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<ul style="list-style-type: none"> • Transmission and reflection at a boundary between two springs (or strings); 	<ul style="list-style-type: none"> • Describe what happens when a pulse meets a boundary between two springs. 		Try to demonstrate this to learners by connecting two different types of springs and sending a pulse from the first one into the second. Then reverse it and send a pulse from the second one into the first one. At the boundary, part of the pulse will be reflected and part will be transmitted.
<ul style="list-style-type: none"> • Relation of pulse speed to medium; 	<ul style="list-style-type: none"> • Know that the pulse speed depends on the properties of the medium and not of the pulse 		
<ul style="list-style-type: none"> • Reflection from a fixed end and a free end; 	<ul style="list-style-type: none"> • Demonstrate and /or draw a diagram to show how a pulse is: <ul style="list-style-type: none"> ○ inverted when reflected from a fixed end ○ not inverted when reflected from a free end 		This is the first time learners encounter boundary conditions, one of the big ideas. Fixed and free ends are examples of boundaries.
<ul style="list-style-type: none"> • Superposition. 	<ul style="list-style-type: none"> • Explain (using diagrams) how two pulses that reach the same point in the same medium superpose <ul style="list-style-type: none"> ○ constructively and ○ destructively and then continue in the original direction of motion • Show how the amplitudes of pulses add together using superposition 		This is the first time learners encounter superposition, another big idea.
<u>Transverse waves:</u>			
<ul style="list-style-type: none"> • Wavelength, frequency, amplitude, period, wave speed; 	<ul style="list-style-type: none"> • Define a wave. • Draw a diagram to represent a transverse wave in a spring, showing the direction of motion of the wave perpendicular to the direction in which the particles move. 		Make a link with the definition of speed as distance travelled/time taken. For a wave the distance travelled in one period is one wavelength, and frequency is 1/period.

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	<ul style="list-style-type: none"> • Identify the wavelength and amplitude on a drawing of a transverse wave, and define these terms. • Explain the terms crest, trough, node and antinodes. • Define the period and frequency of a wave and the relationship between the two quantities. • Derive the equation for wave speed, $v=f\lambda$, from the definition of speed. • Use the equation for wave speed, $v=f\lambda$, to solve problems involving waves. 		
<ul style="list-style-type: none"> • Particle position, displacement, velocity, acceleration; 	<ul style="list-style-type: none"> • Draw a graph to show the transverse position of the particle versus time 	<ul style="list-style-type: none"> • Use the velocity vs time and acceleration vs time graphs of the same particle to describe the motion of the particle. 	
<ul style="list-style-type: none"> • Standing waves with different boundary conditions (free and fixed end) as a kind of superposition 	<ul style="list-style-type: none"> • Describe how a standing wave is generated by interference between the incident and reflected waves • Draw a diagram and label: <ul style="list-style-type: none"> ○ nodes as points where destructive interference takes place ○ anti-nodes as points where constructive interference takes place • Determine the possible values of wavelength and frequency for standing waves in a medium with different boundary conditions, e.g. 	<ul style="list-style-type: none"> • Show, using a simple diagram and the principle of superposition how standing waves result from the interference between incident and reflected waves. 	<p>If a long spring or heavy rope (e.g. a skipping rope) is available, demonstrate standing waves to learners. This will help them appreciate that only certain frequencies of standing waves are possible for a given length and given boundary conditions.</p> <p>In Grade 11 learners will apply what they learn now about standing waves when they study the physics of music and musical instruments.</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 10)

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Constructing and Applying Scientific Knowledge

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	nodes at both ends, node at one end and anti-node at the other.		
<u>Geometrical optics:</u>			
<ul style="list-style-type: none"> • Light rays; 	<ul style="list-style-type: none"> • Give evidence to show that light travels in straight lines • Draw ray diagrams to represent the way in which light travels. • Explain how we are able to see an object using words and light ray diagrams 		<p>Stress that light rays are not real—they are a representation used to indicate the path that light travels.</p> <p>We only see an object when light from the object enters our eyes. The object must be a light source or else it must reflect light from a source, and the reflected light enters our eyes.</p>
<ul style="list-style-type: none"> • Reflection; 	<ul style="list-style-type: none"> • Define ‘the normal’ to a surface, angle of incidence and angle of reflection. • State the relationship between the angle of incidence and the angle of reflection (the Law of Reflection) • Draw a ray diagram to show the relationship between the angle of incidence and the angle of reflection • Explain the difference between specular and diffuse reflection 		
<ul style="list-style-type: none"> • Refraction (change of wave speed in different media); 	<ul style="list-style-type: none"> • Explain refraction in terms of change of wave speed in different media • Define angle of refraction. • Define the refractive index of a medium • State the relationship between the angles of incidence and refraction and the refractive indices of the media when light passes from one 		<p>It is useful to use analogies to explain why light waves bend inwards towards the normal when they slow down (pass into a medium with higher refractive index) or outwards when they speed up (pass into a medium with lower refractive index). One analogy is a lawnmower that moves from a patch of short grass to a patch of long grass.</p>

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	<p>medium into another (Snell's Law)</p> <ul style="list-style-type: none"> • Apply Snell's Law to problems involving light rays passing from one medium into another • Draw ray diagrams showing the path of light when it travels from a medium with higher refractive index to one of lower refractive index and vice versa. 		<p>The tyre in the long grass will go slower than the one in the short grass, causing the path of the lawnmower to bend inwards.</p> <p>In Grade 11 learners will study applications of refraction when they learn about lenses, microscopes and telescopes.</p>
<ul style="list-style-type: none"> • Mirrors; 	<ul style="list-style-type: none"> • Draw a ray diagram to show the position of the image for a plane mirror • List the properties of the image formed in a plane mirror, namely: <ul style="list-style-type: none"> ○ Image is the same distance behind the mirror as the object is in front of the mirror ○ Image is the same size as the object ○ Image is laterally inverted ○ Image is virtual 	<ul style="list-style-type: none"> • Draw ray diagrams to show how light is reflected by a <ul style="list-style-type: none"> ○ convex mirror ○ concave mirror • Explain how light converges to the focal point of a concave mirror and diverges away from the focal point of a convex mirror • Identify the properties of images formed in convex and concave mirrors and their relationship to the position of the object. 	
<ul style="list-style-type: none"> • Total internal reflection, fibre optics in endoscopes and telecommunications. 	<ul style="list-style-type: none"> • Explain what total internal reflection is. • Use Snell's Law to derive an expression for the critical angle for refraction at the surface between a given pair of media. • Explain how optical fibres function and are used in <ul style="list-style-type: none"> ○ endoscopes and ○ telecommunications and give an advantage of each of 		

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	these technological advances over the processes they have replaced		
ELECTRICITY AND MAGNETISM 12,5%			
<u>Magnetism:</u>			
<ul style="list-style-type: none"> • Magnetic field of permanent magnets; 	<ul style="list-style-type: none"> • Explain that a magnetic field is a region in space where another magnet or ferromagnetic material will experience a force (non-contact) • Use words and pictures to explain why permanent magnets have a magnetic field around them by referring to domains. 		Electrons moving inside any object have magnetic fields associated with them. In most materials these fields point in all directions, so the net field is zero. In some materials (ferromagnetic) there are domains, which are regions where these magnetic fields line up. In permanent magnets, many domains are lined up, so there is a net magnetic field.
<ul style="list-style-type: none"> • Poles of permanent magnets, attraction and repulsion; 	<ul style="list-style-type: none"> • Describe a magnet as an object that has a pair of opposite poles, called north and south. Even if the object is cut into tiny pieces, each piece will still have both a N and a S pole. • Apply the fact that like magnetic poles repel and opposite poles attract to predict the behaviour of magnets when they are brought close together • Show the shape of the magnetic field around a bar magnet and a pair of bar magnets placed close together, e.g. using iron filings or compasses. Sketch magnetic field lines to show the shape, size and direction of the magnetic field of different arrangements of bar magnets 		<p>Magnetic fields are different from gravitational and electric fields because they are not associated with a single particle like a mass or a charge. It is never possible to find just a north pole or just a south pole in nature. At the microscopic level, magnetic fields are a product of the movement of charges.</p> <p>Field lines are a way of representing fields. The more closely spaced the field lines are at a point the greater the field at that point. Arrows drawn on the field lines indicate the direction of the field. A magnetic field points from the north to the south pole. Field lines never cross and can be drawn in all three dimensions. For simplicity, only two dimensions are usually shown in</p>

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<ul style="list-style-type: none"> • Earth's magnetic field, compass 	<ul style="list-style-type: none"> • Explain how a compass indicates the direction of a magnetic field. • Compare the magnetic field of the Earth to the magnetic field of a bar magnet using words and diagrams • Explain the difference between the geographical north pole and the magnetic north pole of the Earth. • Give examples of phenomena that are affected by Earth's magnetic field 		<p>drawings.</p> <p>The geographical north pole is determined by the position of the sun. The magnetic north pole is determined by a compass. The magnetic north pole is constantly moving. At present the angle between the two different north poles is about 11.5°.</p> <p>One of the most important effects of the Earth's magnetic field is that it traps charged particles that are blown towards the upper atmosphere by the solar wind and which could damage telecommunications on Earth. These particles spiral along the magnetic field lines until they get close to the Earth's magnetic poles where they collide with air molecules, causing a beautiful glow in the sky called an aurora. A number of animals are able to detect magnetic fields, which helps them orient themselves. These include pigeons, bees, Monarch butterflies, sea turtles and fish.</p>
<p><u>Electrostatics:</u></p>			
<ul style="list-style-type: none"> • Two kinds of charge; 	<ul style="list-style-type: none"> • Provide evidence for the existence of two types of charge and justify the use of the names "positive" and "negative" • Describe how objects (insulators) can be charged by contact (or rubbing) • Apply the law conservation of charge 		<p>It is reasonable to call the two types of charge "positive" and "negative" because when they are added the net charge is zero.</p> <p>Be sure that learners know that all objects contain both positive and</p>

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	to explain that materials charged by contact carry opposite charges of equal magnitude		negative charges, but we only say an object is charged when it has extra positive or negative charges.
<ul style="list-style-type: none"> • Force charges exert on each other (descriptive); 	Recall that <ul style="list-style-type: none"> • like charges repel • opposite charges attract • the force between charges increases when the magnitude of the charges increases or the separation of the charges decreases 		Coulomb's Law is done in Grade 11, so it is only necessary to look at the qualitative relationship between the force charges exert on one another, charge separation and the magnitude of the charges now.
<ul style="list-style-type: none"> • Attraction between charged and uncharged objects (polarisation); 	Explain how charged objects can attract uncharged insulators because of the movement of polarized molecules in insulators		In materials that comprise polarised molecules, these molecules may rotate when brought near to a charged object, so that one side of the object is more positive and the other side more negative, even though the object as a whole remains neutral.
<ul style="list-style-type: none"> • Conductors and insulators 	<ul style="list-style-type: none"> • Describe the difference between conductors and insulators in terms of how easily electrons can move inside them 		Link to Grade 10 Matter and Materials, electrical conductors and insulators
<u>Electric circuits:</u>			
<ul style="list-style-type: none"> • Need for a closed circuit for charges to flow; 	<ul style="list-style-type: none"> • Give evidence for why a closed circuit is needed for charges to flow • Identify and draw symbols for a: resistor, light bulb, battery, switch, voltmeter, ammeter, and connecting leads • Draw simple electric circuit diagrams using symbols • For a given circuit diagram, draw a 		Note that historically a battery was a collection of cells. Nowadays, the term "battery" is used in physics for both. In practice, we do not need to know how many cells are involved. We therefore no longer use the word "cell". This also makes it easier for learners to make a link with their

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	<p>picture of one or more physical circuits and vice versa.</p> <ul style="list-style-type: none"> Given a circuit diagram, set up a circuit; given a circuit, draw the circuit diagram 		<p>everyday experience.</p> <p>Learners should try setting up a circuit to make a light bulb light using a battery and connecting leads. They will find that the bulb will only light if it is part of a closed loop that includes connections to two contacts on the bulb and both ends of the battery.</p> <p>It is important to make the distinction between a circuit diagram and a picture of a circuit. A circuit diagram is a representation of a circuit that only shows electrical connections, not physical connections. It is possible to set up circuits with different layouts that correspond to the same circuit diagram.</p>
<ul style="list-style-type: none"> Electrical potential difference (voltage); 	<ul style="list-style-type: none"> Define electrical potential difference as the difference in electrical potential energy per unit charge between two points. The units are volt (V), which is the same as joule per coulomb. Thus electrical potential difference is also called voltage. Explain why the voltage across resistors arranged in parallel is the same. Explain why the voltage across resistors arranged in series is the sum of the voltages across each resistor. Use the fact that voltage is 		<p>Ohm's Law will be done in Grade 11, so only a qualitative introduction to electrical potential difference, current and resistance is needed now.</p> <p>It is very important to distinguish between voltage and current, as learners often confuse these two concepts. Stress that voltage is the <i>difference</i> in electrical potential energy per unit charge between two points in a circuit. Voltage is therefore always measured between or across two points, such as on either side of a</p>

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	<p>proportional to resistance to calculate what proportion of the total voltage of a circuit will be found across each circuit element.</p> <ul style="list-style-type: none"> • State that the electrical potential difference across the terminals of a battery is called the emf. • Explain that the battery provides the difference in electrical potential energy needed to make charges in a circuit move. • Solve problems in which the voltages across elements in a circuit add up to the emf. 		<p>resistor. It is meaningless to say “voltage through”.</p> <p>The proportion of the total voltage of a circuit that is measured across a particular circuit element is proportional to the resistance of that element.</p> <p>Whenever voltage is measured between the same two <i>electrical</i> points in a circuit, the same value will be obtained, no matter what is connected between those two points. That is why the voltage is the same across parallel branches in a circuit—the voltage is being measured between the same two electrical points.</p> <p>When circuit elements are arranged in series, there will be a difference in potential energy per unit charge across each element. The voltage across the combination of elements in series will thus be the sum of the voltages across each element.</p> <p>It is useful to make an analogy between a situation where there is a difference in gravitational potential energy, such as a hill or inclined surface, and a situation where there is a difference in electrical potential energy, such as a</p>

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			<p>circuit containing a battery. Just as masses will move from a position of higher to lower potential energy in the first case, so charges will move from a position of higher to lower potential energy in the second case.</p> <p>At this stage, learners can ignore the internal resistance of the battery and assume that the emf and the terminal voltage are equal. Then the emf is a circuit equals the sum of the voltage drops across the other elements in the circuit. In Grade 11 learners will study the effects of internal resistance.</p>
<ul style="list-style-type: none"> • Current; 	<ul style="list-style-type: none"> • Define current, I, as the rate of flow of charge. It is measured in ampere (A), which is the same as coulomb per second. • Calculate the current flowing using the equation $I = \frac{Q}{\Delta t}$ • Indicate the direction of the current in circuit diagrams • Determine the current through the battery in a circuit with several resistors in series relative to a circuit with as single resistor. • Determine the current through the battery in a circuit with several resistors in parallel relative to a 		<p>The direction of current in a circuit is from the positive end of the battery, through the circuit and back to the negative end of the battery. In the past, this was called conventional current to distinguish it from electron flow. However, it is sufficient to call it the direction of the current and just mention that this is by convention.</p> <p>A very common misconception many learners have is that a battery produces the same amount of current no matter what is connected to it. While the voltage produced by a battery is constant, the amount of current supplied depends on what is in the circuit.</p>

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	circuit with a single resistor.		<p>circuit.</p> <p>When resistors are connected in series, they act as obstacles to the flow of charge and so the current through the battery is reduced. The current in the battery is inversely proportional to the resistance. When resistors are connected in parallel, they open up additional pathways, each of which allows the same amount of current to flow as a single pathway or branch. The current through the battery therefore increases according to the number of branches.</p>
<ul style="list-style-type: none"> • Resistance; 	<ul style="list-style-type: none"> • Give a microscopic description of resistance in terms of electrons moving through a conductor colliding with the particles of which the conductor (metal) is made and transferring kinetic energy • Define the unit of resistance; one ohm (Ω) is one volt per ampere. • Explain why a battery in a circuit goes flat eventually by referring to the energy transformations that take place in the battery and the resistors in a circuit • Explain why adding resistors in series in a circuit increases the resistance of the circuit but adding resistors in parallel decreases the resistance of the circuit. 	<ul style="list-style-type: none"> ○ Demonstrate (or describe) how to measure resistance directly using a multimeter 	<p>One of the important effects of a resistor is that it converts electrical energy into other forms of energy, such as heat and light.</p> <p>A battery goes flat when all its chemical potential energy has been converted into other forms of energy.</p> <p>Learners will learn how to calculate equivalent resistance in Grade 11. At this stage they just need to be able to explain qualitatively that more resistors in series create a greater obstacle to the flow of charge, which increases the total resistance of the circuit. More resistors in parallel open up more branches along which current can flow,</p>

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			which decreases the total resistance of the circuit. An analogy with the flow of water in hosepipes is useful.
<ul style="list-style-type: none"> Principles and instruments of measurement of voltage (P.D.), current and resistance. 	<ul style="list-style-type: none"> Draw a diagram to show how to correctly connect an ammeter to measure the current through a given circuit element Draw a diagram to show how to correctly connect a voltmeter to measure the voltage across a given circuit element 	<ul style="list-style-type: none"> Explain that a good quality meter used correctly will not significantly change the values it is used to measure and the implications of this are that <ul style="list-style-type: none"> an ammeter has very low resistance a voltmeter has a very high resistance 	<p>Make sure that learners know that the positive side of the meter needs to be connected closest to the positive side of the battery. An ammeter must be connected in series with the circuit element of interest; a voltmeter must be connected in parallel with the circuit element of interest.</p> <p>If possible, give learners the opportunity to connect meters in circuits. If the meters have more than one scale, always connect to the largest scale first so that the meter will not be damaged by having to measure values that exceed its limits.</p>
MATTER AND MATERIALS 25 %			
<p><u>Observing, describing, classifying and using materials - a macroscopic view</u></p>	Learners should be able to	Learners should be able to	
<ul style="list-style-type: none"> The material(s) of which an object is composed. 	<ul style="list-style-type: none"> Introduce the importance of properties of material, e.g. <ul style="list-style-type: none"> Strength Thermal and electrical conductivity Waterproof or not Brittle, malleable or ductile Magnetic or not 		<p>Apply the idea, throughout the rest of this theme, that the properties of a material are determined by its composition.</p> <p>Illustrate that clothing (and/or shelter) for example, is made of materials with particular properties to fit its purpose: warm, dry, safe – biker’s helmet, protected from the sun - wide brimmed hat, wet suit – layer of air inside the</p>

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			suit keeps the wearer warm – air is a good thermal insulator, ...) Pick up detail in the later bullets of this section
<ul style="list-style-type: none"> • Mixtures: heterogeneous and homogeneous. 	<ul style="list-style-type: none"> • Describe the properties of a mixture: <ul style="list-style-type: none"> ○ Component parts not in a fixed ratio ○ Component parts retain their physical properties ○ Components can be separated • Describe a heterogeneous mixture as non-uniform, like a mixture with component parts in different phases, or obviously made of two different components like black motor car oil and water • Describe a homogeneous mixture as a mixture with component parts that are indistinguishable from each other, like all in the same phase (the atmosphere is a mixture of oxygen, nitrogen, argon, ..) or salt water. • Give examples of common mixtures 		Linking macroscopic properties of materials to micro (particle) structure – one of the big ideas
<ul style="list-style-type: none"> • Pure substances: elements and compounds. 	<ul style="list-style-type: none"> • Use microscopic representations for elements compounds and mixtures • Describe an element as a substance that cannot be broken down into simpler substances. • Describe a compound as a substance that can be broken down into two or more elements • Describe pure substances as 		Linking macroscopic properties of materials to micro (particle) structure – one of the big ideas

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	<ul style="list-style-type: none"> ○ all those substances that are not mixtures are pure substances ○ any element or compound ● Classify substances as pure, as compounds or as elements from a description 		
<ul style="list-style-type: none"> ● Names and formulae of substances. 	<ul style="list-style-type: none"> ● Name compounds <ul style="list-style-type: none"> ○ using the names the elements from which they are made, ○ giving the element to the left and lower down on the Periodic Table first e.g. <ul style="list-style-type: none"> ◆ NaCl is called sodium chloride ○ using prefixes ('mono' for one, 'di' for two and 'tri' for three, ...) to indicate the ratio of atoms of component elements in the compound, e.g. <ul style="list-style-type: none"> ◆ CO - carbon monoxide; ◆ NO₂ - nitrogen dioxide ◆ SO₃ - sulphur trioxide ○ by recalling the common names of substances like <ul style="list-style-type: none"> ◆ Water - H₂O ◆ Ammonia - NH₃ ○ using the names of combinations of atoms that recur regularly <ul style="list-style-type: none"> ◆ CaSO₄; MgSO₄; CuSO₄; e.g. calcium sulphate, magnesium sulphate, copper sulphate, ...- so called <u>sulphates</u> ◆ KNO₃; NaNO₃, potassium nitrate, sodium nitrate - so 		<p><u>This section is primarily about the symbolic representation of matter – important to make links with the macro and microscopic representations. E.g. to show the difference between the 2 in 2Ca and H₂O.</u></p> <p><u>Work out formulae from pictures</u></p>

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	<ul style="list-style-type: none"> called <u>nitrates</u> <ul style="list-style-type: none"> ♦ like carbonate, phosphate • write names given formulae • given names write formulae • Given a list of common ions write formulae e.g. sulfides, sulfites, sulfates, • Pay attention to name endings like –ide, -ite and -ate 		
<ul style="list-style-type: none"> • Metals, semimetals and non-metals. 	<ul style="list-style-type: none"> • Classify substances as metals using their properties <ul style="list-style-type: none"> ○ Thermal Conductors ○ Electrical Conductors ○ Shiny metallic luster ○ Malleable ○ Ductile ○ Range in melting points • Identify the metals, their position on the periodic table and their number in comparison to the number of non-metals • Classify substances as non-metals using their properties <ul style="list-style-type: none"> ○ Poor thermal conductors ○ Electrical Insulators ○ Neither malleable ○ nor ductile • Identify the non-metals and their position on the periodic table • Describe semi-metals as having mainly non-metallic properties • Classify semi-metal by their characteristic property of increasing 		<p>Link to electricity and magnetism in Grade 10</p> <p>Link to electronic properties of matter in grade 11</p>

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	conductivity with increasing temperature (the reverse of metals) – two elements meet this classification – silicon • Identify the semi-metals and their position on the periodic table		
• Electrical conductors, semiconductors and insulators.	• Describe how to test and classify materials as: <ul style="list-style-type: none"> ○ Electrical conductors, ○ semiconductors ○ insulators • Give examples of materials that are: <ul style="list-style-type: none"> ○ Electrical conductors, ○ semiconductors ○ insulators • Identify the substances and the ‘appliances or objects’, that are in common daily use in homes and offices, that are specifically chosen because of their electrical properties (conductors, insulators and semi-conductors)		Link to electricity and magnetism in Grade 10 Link to electronic properties of matter in grade 11 There is some overlap between this section and Electricity and magnetism above – this is more descriptive It may be useful to raise the idea that metals have outer electrons, which are free to move, through the crystal lattice, anticipating the atomic theory section below.
• Thermal conductors and insulators.	• Describe how to test and classify materials as: <ul style="list-style-type: none"> ○ Thermal conductors ○ insulators • Give examples of materials that are: <ul style="list-style-type: none"> ○ Thermal conductors ○ Insulators 		It may be useful to raise the idea that metals have outer electrons which are free to move, through the crystal lattice, anticipating the atomic theory section below
• Magnetic and nonmagnetic materials.	• Describe how to test and classify materials as: <ul style="list-style-type: none"> ○ magnetic ○ non-magnetic 		Link to electricity and magnetism in Grade 10 There is some overlap between this section and Electricity and magnetism

Core knowledge and concepts (Learning Outcome 2 - Grade 10)

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Constructing and Applying Scientific Knowledge

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	<ul style="list-style-type: none"> • Give examples of materials that are: <ul style="list-style-type: none"> ○ magnetic (include modern permanent alnico and ceramic magnets, fridge magnets (magnetic material mixed with a polymer) ○ non-magnetic (all but 3 metals!) • Give examples of the use we make of magnets in daily life (in speakers, in telephones, electric motors, as compasses, ..) 		<u>above – this is more descriptive</u>
<u>Particles substances are made of</u>			
<ul style="list-style-type: none"> • Atoms and molecules (simple and giant) 	<ul style="list-style-type: none"> • Describe atoms as the very small particles of which all substances are made • State that the only substances found in atomic form are the noble gases • Describe a molecule as a group of two or more atoms that are attracted to each other by relatively strong forces or bonds • Give examples of molecules based on the above description e.g. <ul style="list-style-type: none"> ○ Small molecules (relatively few atoms per molecule): oxygen, water, petrol, sugar, ○ Giant molecules (millions of atoms per molecule): diamond, a sodium chloride crystal, a metal crystal like a piece of copper, ... • Recognize molecules from models (space filling, ball and stick, ...) • Draw diagrams to represent 		<p>The focus in this theme is to use the concepts atom and molecule (the microscopic) to explain the macroscopic properties of substances. This is attempted by using diagrams to represent the microscopic world of atoms and molecules. . The purpose of the microscopic diagrams is to help learners better link the macroscopic properties to symbolic representations, like chemical symbols and chemical formulae.</p>

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	<p>molecules using circles to represent atoms</p> <ul style="list-style-type: none"> • Represent molecules using <ul style="list-style-type: none"> ○ Molecular formula for small molecules, e.g. O₂, H₂O, C₈H₁₈, C₁₂H₂₂O₁₁, ... ○ Empirical formulae for giant molecules, e.g. C, NaCl, Cu, • Give the formula of a molecule from a diagram of the molecule and vice versa 		
<ul style="list-style-type: none"> • Linking macroscopic properties of materials to micro (particle) structure. • Intermolecular and intramolecular forces (chemical bonds). Physical state and density explained in terms of these forces. Particle kinetic energy and temperature. 	<ul style="list-style-type: none"> • Describe the difference between inter and intra molecular forces <ul style="list-style-type: none"> ○ using a diagram of a group of small molecules; and ○ in words • Represent a common substance, made of small molecules, like water, using diagrams of the molecules, to show microscopic representations of ice (H₂O(s)), water liquid (H₂O(l)) and water vapour (H₂O(g)) • Illustrate the proposition that intermolecular forces increase with increasing molecular size with examples e.g. He, O₂, C₈H₁₈ (petrol), C₂₃H₄₈(wax), • Explain density of material in terms of the number of molecules in a unit volume, e.g. compare gases, liquids and solids • Explain that increasing the temperature of a substance causes the 		<p>Consider using the word “chemical bond rather than intramolecular force as the similarity between the words causes confusion. The main distinguishing characteristic between intermolecular forces and bonds is the magnitude of the force.</p> <p>Link to grade 11 section on chemical bonding – matter and materials</p>

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	<p>movement of particles of which it is composed to increase. Refer to</p> <ul style="list-style-type: none"> ○ Molecules in a substance composed of small molecules (vibrate, rotate, translate) ○ Atoms in giant molecules (vibrate) <ul style="list-style-type: none"> ● Discuss the distribution of kinetic energy amongst the particles of a substance .i.e. different particles move at different speeds and have different kinetic energy ● State that the temperature of a substance is related to the average kinetic energy of the particles of which it is composed ● Explain the relationship between the strength of intermolecular forces and melting points and boiling points of substances composed of small molecules ● Contrast the melting points of substances composed of small molecules with those of giant molecules where chemical bonds must be broken for substances to melt ● Describe viscosity and explain <ul style="list-style-type: none"> ○ how it is related to intermolecular forces between small molecules ○ how it is affected by temperature changes ● Describe thermal expansion of a substance and how it is related to the motion of molecules in a substance 		

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	composed of small molecules e.g. alcohol in a thermometer • Explain the differences between thermal conductivity in non-metals and metals.		
<u>The Atom: basic building block of all matter</u>			
• Models of the atom.	Given a list of key discoveries (or hypotheses) match these to the description of the atom that followed the discovery. Be able to do this for the period starting with the Greek suggestion that atoms constituted matter, through the electrical experiments of the 19 th century, to the discovery of radioactivity, Rutherford's gold foil experiment and the Bohr model.		Historical approach very useful for highlighting nature of science in LO3.
• Atomic mass and diameter.	• Give a rough estimate of the mass and diameter of an atom • Describe and use the concept of relative atomic mass		
• Structure of the atom: protons, neutrons, electrons.	• Given a periodic table or suitable data <ul style="list-style-type: none"> ○ Identify the atomic number of an element ○ Calculate the number of protons present in an atom of an element ○ Calculate the number of electrons present in a neutral atom ○ Calculate the number of neutrons present ○ Calculate the mass number for an isotope of an element 		
• Isotope	• Explain the term isotope		Requires the introduction of a weighted

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	<ul style="list-style-type: none"> Calculate the relative atomic mass of naturally occurring elements from the percentage of each isotope in a sample of the naturally occurring element and the relative atomic mass of each of the isotopes. Represent atoms (nuclides) using the notation ${}^A_Z\text{E}$. 		average. The calculation is included for understanding of the concept rather than mechanical calculation. We recommend the use of the term relative atomic mass to mean relative average atomic mass.
<ul style="list-style-type: none"> Energy quantization and electron configuration. 	<ul style="list-style-type: none"> Explain how line emission spectra implies the energy of the electrons is quantized. Explain the concept of quantization Relate the lines on the atomic spectrum to electron transitions between energy levels 		
<ul style="list-style-type: none"> Periodicity of ionization energy to support the arrangement of the atoms in the Periodic Table. 	<ul style="list-style-type: none"> Describe the term ionization energy and explain how ionization energies are determined Explain the terms first, second, third (and so on) ionization energy Relate the periodicity of successive ionization energies for each particular atom to the number of electrons the atoms has in a particular energy level. 		
<ul style="list-style-type: none"> Successive ionization energies to provide evidence for the arrangement of electrons into core and valence electrons. 	<ul style="list-style-type: none"> Describe electrons in the outer energy level as valence electrons and the electrons in the inner energy levels as core electrons. Deduce the electron configuration of, and draw the energy level diagrams for, the first twenty elements 		
CHEMICAL CHANGE 18,75 %			

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<u>Physical and Chemical Change</u>								
<ul style="list-style-type: none"> • Microscopic interpretation of macroscopic changes (for example changes in conductivity and temperature) 	<ul style="list-style-type: none"> • Explain the differences between a physical and chemical change, i.e. <ul style="list-style-type: none"> ○ Energy transfers involved and their relevant magnitude <ul style="list-style-type: none"> ◆ **Chemical change e.g. chemical reactions: <table border="1"> <tr> <td style="padding: 5px;">Energy transferred</td> <td style="padding: 5px;">=</td> <td style="padding: 5px;">Total energy absorbed to break bonds</td> <td style="padding: 5px;">-</td> <td style="padding: 5px;">Total energy released when new bond form</td> </tr> </table> <ul style="list-style-type: none"> ◆ Physical change e.g. melting, evaporating, boiling <ul style="list-style-type: none"> ○ Particle composition – represent the changes microscopically ○ Forces between particles involved ○ reversibility 	Energy transferred	=	Total energy absorbed to break bonds	-	Total energy released when new bond form		<p><u>Throughout this section cognizance should be taken of representations at macro, micro and symbolic level</u></p>
Energy transferred	=	Total energy absorbed to break bonds	-	Total energy released when new bond form				
<ul style="list-style-type: none"> • Separation of particles in decomposition and synthesis reactions 	<ul style="list-style-type: none"> • Describe that the rearrangement of molecules occurs during physical changes e.g. describe <ul style="list-style-type: none"> ○ molecules as separated when water evaporates to form water vapour ○ disordering of water molecules when ice melts due to breaking of intermolecular forces ○ energy change as small in relation to chemical changes ○ mass, numbers of atoms and molecules as being conserved during these physical changes • Describe examples of a chemical 		<p><u>This bullet point interpreted as: Separation of particles during physical change, decomposition and synthesis reactions as examples of chemical change.</u></p>					

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	<p>change that could include</p> <ul style="list-style-type: none"> ○ The decomposition of hydrogen peroxide to form water and oxygen; and ○ the synthesis reaction that occurs when hydrogen burns in oxygen to form water. Describe <ul style="list-style-type: none"> ◆ the energy involved in these chemical changes as much larger than those of the physical change i.e. hydrogen is used as a rocket fuel. ◆ mass and atoms are conserved during these chemical change but the number of molecules are not. Show this with microscopic diagrams 		
<ul style="list-style-type: none"> • Conservation of atoms and mass. 	<ul style="list-style-type: none"> • Illustrate the conservation of atoms and non-conservation of molecules during chemical reactions using models of reactant molecules (coloured marbles stuck to each other with 'prestik' will suffice) • Draw diagrams representing molecules at a microscopic level to show how the particles have been rearranged in chemical reactions to show that atoms are conserved 		
<ul style="list-style-type: none"> • Law of constant composition 	<ul style="list-style-type: none"> • State the law of constant proportions • Explain that the ratio in a particular compound is fixed as represented by its chemical formula • Give evidence that multiple 		

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	proportions are possible, for example: Water H_2O and peroxide H_2O_2		
<ul style="list-style-type: none"> • Conservation of energy 	<ul style="list-style-type: none"> • Explain the source of energy during a chemical reaction, like the burning of methane, as the difference between the energy input required to break the chemical bonds of the reactant molecules and energy transferred to the surroundings when the bonds of the product molecules form • If during the reaction energy is released to the surroundings, as during burning, the reaction is described as exothermic. • If during the reaction energy is absorbed, as during photosynthesis, the reaction is described as endothermic. 		
<ul style="list-style-type: none"> • Volume relationships in gaseous reactions. 	<ul style="list-style-type: none"> • Describe explosions as exothermic reactions, during which a great many molecules are produced in the gas phase so that there is a massive increase in volume e.g. ammonium nitrate in mining or petrol in a car cylinder 		

<p><u>Representing chemical change</u></p> <ul style="list-style-type: none"> Balanced chemical equations 	<ul style="list-style-type: none"> Represent chemical changes using reaction equations i.e. translate word equations into chemical equations <ul style="list-style-type: none"> with formulae with subscripts to represent phases (s), (l), (g) and (aq) Balance reaction equations by <ul style="list-style-type: none"> using models of reactant molecules (coloured marbles stuck to each other with 'prestik' will suffice) and rearranging the 'atoms' to form the products by conserving atoms representing molecules at a microscopic level using coloured circles and simply rearranging the pictures to form the product molecules by 'conserving atoms'. by inspection using reaction equations Interpret balanced reaction equations in terms of <ul style="list-style-type: none"> conservation of atoms conservation of mass (use relative atomic masses) volume relationships for gases under the same conditions of temperature and pressure (volume of gaseous is directly proportional to the number of particles) energy transferred 		<p><u>Throughout this section cognisance should be taken of representations at macro, micro and symbolic level</u></p>
<p>CHEMICAL SYSTEMS 18,75 %</p> <p>The content and context provides opportunities to focus assessment on Learning Outcome 3, viz. evaluating</p> <ul style="list-style-type: none"> competing knowledge claims the impact of science on human development the impact of science on the environment <p>It is important that teachers create the opportunities for learners to</p> <ul style="list-style-type: none"> practice the skills they require to make such evaluations by getting them to 			

- know the structure of a scientific argument and use it (“Guess-deduce-test”; Identify the proposition/hypothesis, collect evidence that supports / refutes the proposition/hypothesis, evaluate the evidence (against relevant criteria), draw conclusions (refute/accept the hypothesis) from the evidence and substantiate the conclusion using the evidence.)
- select the relevant issues, e.g. from, say;
 - ◆ waste management,
 - ◆ use of energy (electricity),
 - ◆ use of (non-renewable) resources,
 - ◆ environmental issues ...
 - ◆ benefits to humans, positive impact on the environment say, ...
- develop the skills they require to identify (from supplied data or a text or their own knowledge) the subject content they need to substantiate their arguments, viz.
 - Use a knowledge of hazardous materials to identify risk associated with particular events/processes, e.g. manufacture and transport of fuels – fire risk, CO₂, CH₄, – greenhouse gases, CFC’s – negative impact on the ozone layer, Cl₂, Hg ... - toxic, oxides of nitrogen are produce by cars, CO₂ by cars and CO₂ and SO₂ and coal burning power stations during the generation of electricity – these gases are responsible for acid rain, smoke and ash (from furnaces) can cause lung diseases, and so on
 - Use criteria against which to evaluate the impact on humans, e.g. (health/ productivity – jobs / convenience/ technology (cell phones) / entertainment / safety / wealth creation
 - Use criteria against which to evaluate the impact on the environment (sustainable development), e.g. (global warming/ exploitation of non-renewable resources/ ozone layer / eutrophication / solid waste - land fills; nuclear waste,

Global cycles:			
* The water cycle:			
<ul style="list-style-type: none"> • Physical changes and energy transfers: The movement of water from the ocean and land surfaces as controlled by energy in sunlight. Reservoirs for water on Earth. 	<ul style="list-style-type: none"> • Describe the water cycle as a set of physical changes in which water undergoes evaporation, condensation, precipitation • Identify the different reservoirs of water on Earth • Explain how sunlight drives the movement of water <ul style="list-style-type: none"> ○ in the water cycle ○ to set up weather systems in the atmosphere • List the importance of the water cycle for life on Earth 		
<ul style="list-style-type: none"> • Macroscopic properties of the three phases of water related to their microscopic structure. 	<ul style="list-style-type: none"> • Describe the shape of the water molecule and its polar nature • State that it is due to the polar nature (polar nature) of the water molecule that water absorbs infra-red radiation (heat) from the sun. As a 		<p><u>This is the first mention of polar molecules so a short introduction to polar molecules and the properties is necessary here. Also link to intermolecular forces above</u></p>

	<p>consequence the sea acts as reservoir of heat and is able to ensure the Earth has a moderate climate.</p> <ul style="list-style-type: none"> • Explain that because of its polar nature and consequent hydrogen bonding that <ul style="list-style-type: none"> ○ there are strong forces of attraction between water molecules (hydrogen bonds) that cause water to have <ul style="list-style-type: none"> ◆ a high latent heat, ◆ a high specific heat ◆ a high heat of vaporization, and ◆ large difference between melting point and boiling point ○ the density of the ice is less than the density of the liquid and ice floats on water forming an insulating layer between water and the atmosphere keeping the water from freezing and preserving aquatic life 		
<p>* <u>The nitrogen cycle:</u></p>			
<ul style="list-style-type: none"> • Chemical changes and energy transfers. The movement of nitrogen between interrelated biological and geological systems. 	<ul style="list-style-type: none"> • Give chemical equations wherever relevant • Describe the role that nitrogen plays as essential to the production of proteins which are essential for all life • Describe atmospheric nitrogen as inert and the need to get nitrogen to react to produce soluble nitrate salts and ammonia or ammonium salts that can be used by plants as a source of nitrogen • Describe the formation of oxides of nitrogen and eventually nitrates as nitrogen fixing • Describe the role of lightning in 		<p><u>Link to fertilizer under chemical systems in Grade 12</u></p>

	<p>nitrogen fixing</p> <ul style="list-style-type: none"> • Describe the role of bacteria in nitrogen fixing • Describe the role of the combustion engine in nitrogen fixing and atmospheric pollution • Contrast the nitrogen cycle in which nitrogen atoms react chemically to form different molecules and ions at each stage of the cycle as opposed to the water cycle which incorporates only physical changes • Describe the negative consequences of mans interference in the nitrogen cycle <ul style="list-style-type: none"> ○ Motor car exhaust emissions of oxides of nitrogen produce <ul style="list-style-type: none"> ◆ acid rain ◆ green house gases and global warming ◆ nitrogen dioxide pollution of the air ○ excessive use of inorganic fertilizers contributes to the eutrophication of water ways and dams • Describe the role of bacteria in returning nitrogen to the atmosphere 		
• Industrial fixation of nitrogen	<ul style="list-style-type: none"> • Describe industrial processes designed to fix nitrogen and make inorganic fertilizers – Haber Process • Describe the Ostwald process to produce nitric acid • Describe the production of ammonium nitrate by the neutralization of ammonia with nitric acid 		<u>Good opportunity to use the life story of Haber and address LO3</u>
<u>The hydrosphere</u>			
• Its composition and interaction with other global systems.	<ul style="list-style-type: none"> • Identify the hydrosphere and give an overview of its interaction with the atmosphere, the lithosphere and the biosphere. Water moves through 		

	<ul style="list-style-type: none"> ○ air (atmosphere) ○ rocks and soil (lithosphere) ○ plants and animals dissolving and depositing, cooling and warming, ...		
<ul style="list-style-type: none"> • Ions in aqueous solution: their interaction and effects. 	<ul style="list-style-type: none"> • Explain, using diagrams representing interactions at the microscopic level, with reference to the polar nature of the water molecule how water is able to dissolve ions • Represent the dissolution process using balanced reaction equations using the abbreviations (s) and (aq) appropriately • Explain with appropriate reaction equations how the passage of water through the atmosphere dissolves gases, CO₂, SO₂ and NO₂ that give rise to acid (rain – mostly carbonic acid) • Explain with appropriate reaction equations where relevant <ul style="list-style-type: none"> ○ how the passage of acidified water (carbonic acid) through the lithosphere, dissolves calcium carbonate to form calcium ions, Ca²⁺, ○ that together with other ions like Mg²⁺, cause hardness in water ○ what hard water is, and ○ how using ion exchange water is softened ○ the concept of pH and the pH scale as a measure of acidity ○ the ions responsible for acidity and alkalinity ○ the pH of (rain) water and soils ○ the role of clay in providing the metal ions needed by plants, through a process of ion exchange 		<p>Link to acids and bases in grade 11 under chemical change – types of reaction.</p>
<ul style="list-style-type: none"> • Electrolytes and extent of ionization as measured by 	<ul style="list-style-type: none"> • Explain with appropriate reaction equations how the passage of water 		

conductivity	<p>through the lithosphere dissolves ions that give rise to increasing conductivity of the water</p> <ul style="list-style-type: none"> • Describe a simple circuit to measure conductivity of solutions • Relate conductivity to <ul style="list-style-type: none"> ○ the concentration of ions in solution and this in turn to the solubility of particular substances, however ○ the type of substance, since some substances, like sugar, dissolve but this does not affect conductivity, conductivity will not always be a measure of solubility • Explain that when substances dissolve to form ions this is a chemical process, as opposed to when sugar dissolves in water and no ions form, no chemical bonds break or are made and this is a physical process. 		
• Precipitation reactions.	<ul style="list-style-type: none"> • Write balanced reaction equations to describe precipitation of insoluble salts • Explain how to test for the presence of the following anions in solution: <ul style="list-style-type: none"> ○ Chloride – using silver chloride and nitric acid ○ Bromide- using silver chloride and nitric acid ○ Iodide -using silver chloride and nitric acid ○ Sulphate – using barium nitrate and nitric acid ○ Carbonate –using silver chloride, barium nitrate and acid (precipitate dissolves in nitric acid) • Identify an ion or ions in a solution from a description of the reactants mixed and the observations that followed. 		

Core knowledge and concepts (Learning Outcome 2 - Grade 11)

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MECHANICS 12,5%:			
<u>Force, momentum and impulse:</u>			
<ul style="list-style-type: none"> • Pairs of interacting objects exert equal forces on each other (Newton's Third Law); 	<ul style="list-style-type: none"> • State Newton's Third Law (N3): When pairs of objects interact they exert forces on each other. These forces are the same size and point in opposite directions. • Differentiate between contact and non-contact forces • Apply Newton's Third Law (N3) to contact and non-contact forces • Identify N3 pairs e.g. donkey pulling a cart, a book on a table 		<p>Newton's Third Law (N3) is a source of great confusion for students. Stress that <i>pairs</i> of objects interact; as a result each object exerts a force on the other one of the same size.</p> <p>Do not use the words "action" and "reaction" because learners might think that first one force acts and then the other. Both forces act simultaneously.</p>
<ul style="list-style-type: none"> • Momentum; 	<ul style="list-style-type: none"> • Define momentum • Calculate the momentum of a moving object using $p = mv$ • Describe the vector nature of momentum and illustrate with some simple examples 		
<ul style="list-style-type: none"> • A net force on an object causes a change in momentum – if there is no net force on an object/system its momentum will not change (momentum will be conserved); 	<ul style="list-style-type: none"> • State Newton's Second Law (N2) in terms of momentum: the net (or resultant) force acting on an object is equal to the rate of change of momentum. • Express N2 in symbols: $F_{net} = \frac{\Delta p}{\Delta t}$ • Explain the relationship between net force and change in momentum for a 		<p>This is the general form of Newton's Second Law. The form $F=ma$ applies only to the special case when the mass is constant, and should be presented as such.</p> <p>By introducing momentum now, the common confusion between momentum and force can be addressed.</p> <p>Stress that the motion of an object, and</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 11)

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	<p>variety of motions.</p> <ul style="list-style-type: none"> • Calculate the change in momentum when a resultant force acts on an object and its velocity <ul style="list-style-type: none"> ○ increases in the direction of motion (e.g. 2nd stage rocket engine fires) ○ decreases (e.g. brakes are applied) ○ reverses its direction of motion e.g. a soccer ball kicked back in the direction it came from <p>Draw vector diagrams to illustrate the relationship between the initial momentum, the final momentum and the change in momentum in each of the above cases</p> <ul style="list-style-type: none"> • Know that in the absence of an external force acting on a system momentum is conserved • m • Apply the conservation of momentum to collisions of two objects. <ul style="list-style-type: none"> ○ moving in one dimension (along a straight line) 		<p>therefore its momentum, only changes when a net (resultant) force is applied. Conversely, a net force causes an object's motion, and therefore its momentum, to change.</p> <p>At this point it might be useful to use vector representation.</p>
<ul style="list-style-type: none"> • Impulse (product of net force and time for which it acts on an object, momentum change); 	<ul style="list-style-type: none"> • Define impulse as $F\Delta t$ • Know that $F\Delta t$ is a change in momentum, i.e. $F\Delta t = \Delta p$. • Use the relationship between impulse and change in momentum to calculate the force exerted, time for which the force is applied and 		<p>A very important application of impulse is improving safety and reducing injuries. In many cases, an object needs to be brought to rest from a certain initial velocity. This means there is a certain specified change in momentum. If the time during which</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 11)

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	<p>which the force is applied and change in momentum for a variety of situations involving the motion of an object in one dimension</p> <ul style="list-style-type: none"> Apply the concept of impulse to safety considerations in everyday life, e.g. airbags, seatbelts and arrestor beds. 		<p>the momentum changes can be increased then the force that must be applied will be less and so it will cause less damage. This is the principle behind arrestor beds for trucks, airbags, and bending your knees when you jump off a chair and land on the ground.</p>
<ul style="list-style-type: none"> a net force causes an object to accelerate (Newton's Second Law); 	<ul style="list-style-type: none"> State Newton's Second Law in the special case of constant mass: the net force exerted on an object equals its mass times its acceleration. State Newton's First Law: An object continues in a state of rest or moving with constant velocity unless it is acted on by an unbalanced (net) force. Draw force diagrams for objects at rest, moving with constant velocity and accelerating. Draw free body diagrams for objects at rest, moving with constant velocity and accelerating. Calculate the acceleration of a single object on which several forces act simultaneously Calculate the acceleration of two objects that are joined together, e.g. two masses joined by a string. 		<p>For static situations and uniform velocity, all the forces in the x-direction and all the forces in the y-direction must add up to zero. This is another context in which the idea of superposition can be applied.</p> <p>When an object accelerates, the equation $F_{\text{net}} = ma$ must be applied separately in the x and y directions. If there is more than one object, a free body diagram must be drawn for each object and N2 must be applied to each object separately.</p> <p>It is important to distinguish between a force diagram and a free body diagram. A force diagram is a picture of the object(s) of interest with all the forces acting on it (them) drawn in as arrows. In a free-body diagram, the object of interest is drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot.</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 11)

The learner is able to state, explain, interpret and evaluate scientific and technological knowledge and can apply it in everyday contexts.

Constructing and Applying Scientific Knowledge

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			Be very careful to help learners distinguish between when to use N3 (when <i>pairs</i> of objects interact) and when to use N2 (when the forces acting on <i>one</i> object are being considered).
<ul style="list-style-type: none"> • Objects in contact exert forces on each other (e.g. normal force, frictional force); 	<ul style="list-style-type: none"> • Identify a variety of contact forces, e.g. pushes, pulls, tension, normal and friction forces. • Know that a surface exerts two types of contact forces, a normal force and a friction force perpendicular and parallel to the surface, respectively. • Distinguish between static and dynamic friction forces and explain why there is difference. • Calculate the value of the static friction force for an object at rest and of the dynamic friction force for a moving object. • Solve problems for objects on a horizontal surface and on an incline. 		<p>Normal forces are exerted at right angles to any surface by both objects that are in contact. For example, when a book rests on a table, the table exerts a normal force upwards on the book and the book exerts a normal force downwards on the table.</p> <p>The force of static friction can have a range of values from zero up to a maximum value, $\mu_s N$. The force of dynamic friction on an object is constant for a given surface and equals $\mu_d N$.</p> <p>Friction forces can be explained in terms of the interlocking of the irregularities in surfaces, which impedes motion.</p> <p>Be careful when solving problems involving objects on an inclined surface because the normal force acting on the object is not equal to its weight.</p>
<ul style="list-style-type: none"> • Masses can exert forces on each other (gravitational 	<ul style="list-style-type: none"> • Understand that objects can interact with a field, which is how masses 		Remind learners that they have already met these ideas in Grade 10. Remind

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attraction) without being in contact, fields;	<p>with a field, which is how masses can exert forces on each other without touching.</p> <ul style="list-style-type: none"> • Know that gravitational field strength 'g' is the force per unit mass, $g = F/m$, with an approximate value of $9.8\text{m}\cdot\text{s}^{-2}$ on or near the surface of the Earth. • Know that the weight of an object is the force the Earth exerts on the object on or near the surface of the Earth ($w = mg$) 		them that a field is a region of space in which an object experiences a force.
<ul style="list-style-type: none"> • Force two masses exert on each other (Newton's Law of Universal Gravitation); 	<ul style="list-style-type: none"> • State Newton's Law of Universal Gravitation • Use the equation for Newton's Law of Universal Gravitation to calculate the force two masses exert on each other 		
<ul style="list-style-type: none"> • Moment of force, mechanical advantage. 	<ul style="list-style-type: none"> • Know that when an object is fixed or supported at one point and a force acts on it a distance away from the support, it tends to make the object turn. • Know that the moment of a force, or torque, is the product of the distance from the support and the component of the force perpendicular to the object. • Calculate the moment of the force, or torque, due to each force when several forces act on the same object using the equation: 		<p>Any component of a force exerted parallel to an object will not cause the object to turn. Only perpendicular components cause turning.</p> <p>The direction of the moment of a force, or torque, is either clockwise or anticlockwise. When moments are summed, choose one direction as positive and the opposite direction as negative. If equal clockwise and anticlockwise torques are applied to an object, they will cancel out and there will be no net turning effect.</p>

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	$\tau = F_{\perp} r$ <ul style="list-style-type: none"> Know that for an object to be in equilibrium both the sum of the forces acting on the object and the sum of the moments of the forces must be zero. Solve problems involving objects in equilibrium. Describe the terms “load” and “effort” for a lever Define “mechanical advantage” as the ratio of “load/effort” and calculate the mechanical advantage for simple levers Apply the concept of mechanical advantage to everyday situations. 		<p>There are many examples in everyday life in which objects can be moved more easily by increasing the mechanical advantage, e.g. by inserting a plank that rests on a support under a heavy object and applying a force far from the support.</p>
WAVES, SOUND AND LIGHT 12,5%			
<u>Geometrical optics:</u>			
<ul style="list-style-type: none"> lenses, image formation, gravitational lenses, spectacles, the eye; 	<ul style="list-style-type: none"> Describe the two general types of lenses, those that converge parallel beams of light (converging lenses), and those that diverge parallel beams of light (diverging lenses). Describe all converging lenses as thicker in the middle than at the edge (convex), and all diverging lenses as thicker at the edge than in the middle (concave). . 	<ul style="list-style-type: none"> State that the gravitational field of massive objects like galaxies, black holes and massive stars bend rays of light that pass close-by in accordance with predictions made by Einstein’s Theory of General Relativity, and therefore act as a kind of gravitational lens, distorting, and altering the apparent position of, the image of a star. Describe how astigmatism is 	<p>Learners should not try to memorise the ray diagrams for different lenses and object positions. The image of a point on an object can be located as follows:</p> <ol style="list-style-type: none"> For a converging lens, draw one ray from the point on the object straight through the centre of the lens. Draw a second ray from the object, parallel to the optic axis, and passing through the focal point

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	<ul style="list-style-type: none"> • Define optic axis focal point and focal length (f). • Draw ray diagrams for converging and diverging lenses to locate the position of the image when the object is placed at distances from the lens greater than $2f$, equal to $2f$, between $2f$ and f, and less than f. • Describe the image in each of the cases mentioned above. • Describe how the human eye has a converging lens to create real, inverted, reduced images on the retina at the back of the eye. Focusing is achieved by muscles, which change the focal length of the lens. • Understand the meanings of long-sightedness, short-sightedness and astigmatism what causes these defects of vision. • Use simple diagrams to show how converging lenses can correct long-sightedness and diverging lenses can correct short-sightedness. 	<p>corrected by a special lens, which has different focal lengths in the vertical and horizontal planes.</p>	<p>on the other side of the lens. The image position is where these two lines cross.</p> <p>2. For a diverging lens, draw one ray from the point on the object straight through the centre of the lens. Draw a second ray from the object, parallel to the optic axis that emerges on the other side of the lens at an angle that makes it look as if it came from the focal point on the same side of the lens as the object. Extend this ray back to this focal point using a dotted line. The image position is where the two lines cross.</p>
<ul style="list-style-type: none"> • Telescopes, SALT; 	<ul style="list-style-type: none"> • Draw ray-diagrams illustrating image formation by the refracting astronomical telescope and the reflecting telescope. • Know about the kinds of telescopes used at the Sutherland Observatory in the Western Cape and about the 		<p>Here is an excellent opportunity to contextualise the curriculum for South Africa. With the building of SALT, South Africa has become a world leader in optical telescopes.</p>

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	new SALT (South African Large Telescope).		
<ul style="list-style-type: none"> • Microscopes 	<ul style="list-style-type: none"> • Draw a ray diagram showing how a compound microscope uses two converging lenses to produce a magnified image of a tiny object. 		

<u>Longitudinal waves:</u>			
<ul style="list-style-type: none"> • On a spring; 	<ul style="list-style-type: none"> • Generate a longitudinal wave in a spring • Draw a diagram to represent a longitudinal wave in a spring, showing the direction of motion of the wave relative to the direction in which the particles move. • 		
<ul style="list-style-type: none"> • Wavelength, frequency, amplitude, period, wave speed; 	<ul style="list-style-type: none"> • Defined the wavelength and amplitude of a longitudinal wave • Define compression and rarefaction • Define the period and frequency of a longitudinal wave and the relationship between the two quantities. • Use the equation for wave speed, $v=f\lambda$, to solve problems involving longitudinal waves. ○ 		
<ul style="list-style-type: none"> • Particle position, displacement, velocity, acceleration; 	<p>Explain the motion of a particle of the medium through which a longitudinal wave travels in terms of its</p> <ul style="list-style-type: none"> • position • displacement • velocity and • acceleration 		
<ul style="list-style-type: none"> • Sound waves. 	<ul style="list-style-type: none"> • Explain that sound waves are created by vibrations in a medium in the direction of propagation. The vibrations cause a regular variation in pressure in the medium • Describe a sound wave as a longitudinal wave • • Explain the relationship between wave speed and the properties of the medium in which the wave travels (gas, liquid or solid) 		<p>Learners should understand that sounds waves are pressure waves. For this reason, the more closely spaced the molecules of the medium, the faster the wave travels. That is why sound travels faster in water than in air and faster in steel than in water.</p>

Sound:			
<ul style="list-style-type: none"> • Pitch, loudness, quality (tone); 	<ul style="list-style-type: none"> • Relate the pitch of a sound to the frequency of a sound wave • Relate the loudness of a sound to both the amplitude of a sound wave and the sensitivity of the human ear • Relate the quality of a sound to the harmonics that are superposed in a given sound wave • 		<p>The human ear is more sensitive to some frequencies than to others. Loudness thus depends on both the amplitude of a sound wave and its frequency (whether it lies in a region where the ear is more or less sensitive).</p> <p>Make a link between the quality of the sound and the standing waves produced in different musical instruments. The quality of the sound produced by a particular instrument depends on which harmonics are superposed and in which proportions.</p>
<ul style="list-style-type: none"> • Physics of the ear and hearing; 	<ul style="list-style-type: none"> • Identify the important features on simple diagram of the human ear showing the outer ear, eardrum, ear canal, ossicles, inner ear and auditory nerve. • Refer to the features listed above to explain how sound is transmitted from the outer ear to the auditory nerve, from where a signal is sent to the brain. • • State that the intensity of sound is measured in decibels (dB). • Indicate the relative intensities of a variety of sounds • Explain the dangers of exposure to very loud sounds and what can be done to reduce these dangers. 		<p>Learners should get a table of intensities for a variety of different sounds. They should know that permanent damage can be caused by exposure to very loud sounds. This is an opportunity to discuss the importance of safety equipment such as ear protectors for workers in loud environments, e.g. those who use jack hammers or direct airplanes to their parking bays.</p>
<ul style="list-style-type: none"> • Ultrasound. 	<ul style="list-style-type: none"> • Describe sound with frequencies higher than 20 kHz as ultrasound, up to about 100 kHz. • Explain how an image can be created using ultrasound based on the fact that when a wave encounters a boundary between two media, part of the wave is reflected and part is 		<p>Make a link to Grade 10, reflection and transmission at a boundary. When an ultrasound wave travels inside an object comprising different materials such as the human body, each time it encounters a boundary, e.g. between bone and muscle, or muscle and fat, part of the wave is reflected and part of</p>

	<p>of the wave is reflected and part is transmitted.</p> <ul style="list-style-type: none"> Describe some of the medical benefits and uses of ultrasound, e.g. safety, diagnosis, treatment, pregnancy. ○ 		<p>it is transmitted. The reflected rays are detected and used to construct an image of the object.</p>
Physics of music:			
<ul style="list-style-type: none"> Standing waves in different kinds of instruments. 	<ul style="list-style-type: none"> Describe how sounds are produced in string and wind instruments in terms of standing waves. Draw pictures to show the fundamental and higher frequency harmonics for standing waves on a string fixed at both ends and in a pipe open at one end and open at both ends. Calculate the frequency and wavelength for various harmonics for different wind and string instruments. 		<p>Make a link to Grade 10 standing waves with different boundary conditions. The boundary conditions for a string fixed at both ends are that there must be nodes at both ends. For a pipe open at one end and closed at the other there must be an antinode at one end and a node at the other. For a pipe open at both ends there must be antinodes at both ends.</p>
ELECTRICITY AND MAGNETISM 12,5%			
Electrostatics:			
<ul style="list-style-type: none"> Forces charges exert on each other (Coulomb's Law); 	<ul style="list-style-type: none"> State Coulomb's Law, which can be represented mathematically as $F = \frac{kQ_1Q_2}{r^2}$ Solve problems using Coulomb's Law to calculate the force exerted on a charge by one or more charges in one dimension. 	<ul style="list-style-type: none"> Solve problems using Coulomb's Law to calculate the force exerted on a charge by one or more charges in two dimensions. 	<p>Here is another context in which to apply superposition—the forces exerted on a charge due to several other charges can be superposed to find the net force acting on the charge.</p> <p>Make a link to Grade 11 Mechanics. Get learners to draw free body diagrams showing the forces acting on charges. Also link to N3-- two charges exert forces of equal magnitude on one another in opposite directions.</p> <p>When substituting into the Coulomb's Law equation, it is not necessary to include the signs of the charges. Instead, select a positive direction. Then forces that tend to move the</p>

		charge in this direction are added, while forces that act in the opposite direction are subtracted.
		Make a link with Grade 11 Mechanics, Newton's Law of Universal Gravitation. The two equations have the same form. They both represent the force exerted by particles (masses or charges) on each other that interact by means of a field.
<ul style="list-style-type: none"> • Electric field around single charges and groups of charges; 	<ul style="list-style-type: none"> • Describe an electric field as a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point. • Draw electric field lines for various configurations of charges. • Define the magnitude of the electric field at a point as the force per unit charge ($E = F/q$). E and F are vectors. • Deduce that the force acting on a charge in an electric field is $F = Eq$ • Calculate the electric field at a point due to a number of point charges, using the equation $E = \frac{kQ}{r^2}$ to determine the contribution to the field due to each charge. 	<p>Here is another opportunity to discuss field, one of the big ideas. Discuss the fact that electric field lines, like magnetic field lines (see Grade 10), are a way of representing the electric field at a point. Arrows on the field lines indicate the direction of the field, i.e. the direction a positive test charge would move. Electric field lines therefore point away from positive charges and towards negative charges. Field lines are drawn closer together where the field is stronger. Also, the number of field lines passing through a surface is proportional to the charge enclosed by the surface.</p> <p>The electric fields due to a number of charges can be superposed. As with Coulomb's Law calculations, do not substitute the sign of the charge into the equation for electric field. Instead, choose a positive direction, and then either add or subtract the contribution to the electric field due to each charge depending upon whether it points in the positive or negative direction, respectively.</p>
<ul style="list-style-type: none"> • Electrical potential energy and potential; 	<ul style="list-style-type: none"> • Define the electrical potential energy of a charge as the energy it has because of its position relative to 	Electrical potential energy due to other charges can be positive or negative depending on whether the force

	<p>other charges that it interacts with</p> <ul style="list-style-type: none"> • Use the equation $U = \frac{kQ_1Q_2}{r}$ to calculate the potential energy of a charge due to other charges. • Define the electric potential at a point as the electrical potential energy per unit charge, i.e. the potential energy a positive test charge would have if it were placed at that point. • Explain lightning in terms of electric potential and potential difference and describe measures that can be taken to reduce the risk of being struck by lightning 		<p>between the charges is attractive (U is negative) or repulsive (U is positive).</p> <p>Link electric potential to voltage (Grade 10 and 11), which is the potential difference between two points in a circuit.</p> <p>Lightning provides a good everyday context in which to show the dangers associated with a high potential difference. Since lightning is so common in South Africa and causes so much damage, it is worth spending time discussing it and helping learners think about how to protect themselves and their families.</p>
<ul style="list-style-type: none"> • Capacitance, physics of the parallel plate capacitor, relation between charge, potential difference and capacitance; 	<ul style="list-style-type: none"> • Describe a parallel plate capacitor as a device that consists of two oppositely charged conducting plates separated by a small distance, which stores charge. • Define capacitance as the charge stored per volt, measured in farad (F). Mathematically, $C=Q/V$. • Solve problems involving the charge stored by, and voltage across, capacitors. • Use the equation $C = \epsilon_0 \frac{A}{d}$ to determine the capacitance of a capacitor of given dimensions or design a capacitor of given capacitance. • Calculate the electric field between the plates of a parallel plate capacitor using the equation $E=V/d$. • Explain using words and pictures why inserting a dielectric between the plates of a parallel plate capacitor increases its capacitance. 		<p>Note that Q is the magnitude of the charge stored on either plate, not on both plates added together. Since one plate stores positive charge and the other stores negative charge, the total charge on the two plates is zero.</p> <p>When a dielectric is inserted between the plates of a parallel plate capacitor the dielectric becomes polarised so an electric field is induced in the dielectric that opposes the field between the plates. When the two electric fields are superposed, the new field between the plates becomes smaller. Thus the voltage between the plates decreases so the capacitance increases.</p>

<ul style="list-style-type: none"> • Capacitor as a circuit device. 	<ul style="list-style-type: none"> • Describe what happens to a capacitor in a DC circuit over time. • Describe how a charged capacitor can be used to provide a large potential difference for a very short time. 		<p>When a capacitor is connected in a DC circuit, current will flow until the capacitor is fully charged. After that, no further current will flow. If the charged capacitor is connected to another circuit with no source of emf in it, the capacitor will discharge through the circuit, creating a potential difference for a short time. This is useful, for example, in a camera flash.</p>
<u>Electromagnetism:</u>			
<ul style="list-style-type: none"> • Magnetic field associated with current; 	<ul style="list-style-type: none"> • Provide evidence for the existence of a magnetic field near a current carrying wire. • Use the Right Hand Rule to determine the magnetic field associated with: (i) a straight current carrying wire, (ii) a current carrying loop of wire and (iii) a solenoid. 		<p>A simple form of evidence for the existence of a magnetic field near a current carrying wire is that a compass needle placed near the wire will deflect (link to Grade 10). Try to give learners the opportunity to observe this.</p>
<ul style="list-style-type: none"> • Current induced by changing magnetic field 	<ul style="list-style-type: none"> • State Faraday’s Law. • Use words and pictures to describe in words and pictures what happens when a bar magnet is pushed into or pulled out of a solenoid connected to an ammeter. • Use the Right Hand Rule to determine the direction of the induced current in a solenoid when the north or south pole of a magnet is inserted or pulled out. • Calculate the induced emf and induced current for situations involving a changing magnetic field using the equation for Faraday’s Law: $\mathcal{E} = -N \frac{\Delta\phi}{\Delta t}$ <p>where $\phi=BA$ is the magnetic flux.</p>		<p>Stress that Faraday’s Law relates induced emf to the rate of change of <i>flux</i>, which is the product of the magnetic field and the cross-sectional area the field lines pass through. When the north pole of a magnet is pushed into a solenoid the flux in the solenoid increases so the induced current will have an associated magnetic field pointing out of the solenoid (opposite to the magnet’s field). When the north pole is pulled out, the flux decreases, so the induced current will have an associated magnetic field pointing into the solenoid (same direction as the magnet’s field) to try to oppose the change.</p> <p>The directions of currents and associated magnetic fields can all be found using only the Right Hand Rule.</p>

			When the fingers of the right hand are pointed in the direction of the current, the thumb points in the direction of the magnetic field. When the thumb is pointed in the direction of the magnetic field, the fingers point in the direction of the current.
<ul style="list-style-type: none"> Transformers; 	<ul style="list-style-type: none"> Draw a sketch of the main features of a transformer Use Faraday's Law to explain how a transformer works in words and pictures. Use the equation for Faraday's Law to derive an expression involving the ratio between the voltages and number of windings in the primary and secondary coils. Use the expression $\frac{V_s}{V_p} = \frac{N_s}{N_p}$ to perform calculations for transformers with various specifications. State the difference between a step up and a step down transformer in both structure and function. Give an example of the use of transformers 		<p>The essential features of a transformer are two coils of wire, called the primary and the secondary, which are wound around different sections of the same iron core. When an alternating voltage is applied to the primary coil it creates an alternating current in that coil, which induces an alternating magnetic field in the iron core. This changing magnetic field induces an emf, which creates a current in the secondary coil.</p> <p>Transformers are very important in the supply of electricity nationally. In order to reduce energy losses due to heating, electrical energy is transported from power stations along power lines at high voltage and low current. Transformers are used to step the voltage up from the power station to the power lines, and step it down from the power lines to buildings where it is needed.</p>
<ul style="list-style-type: none"> Motion of a charged particle in a magnetic field. 	<ul style="list-style-type: none"> State that when a charged particle moves through a magnetic field it experiences a force. Use the equation $F=qvB$ to calculate the force exerted on a charge that moves at right angles to a magnetic field. Use the Right Hand Rule to determine the direction of the force. Explain how this effect is used in a television 		<p>To use the Right Hand Rule to find the direction of the force the magnetic field exerts on the moving charge, point your fingers in the direction of the velocity of the charge and turn them (as if turning a screwdriver) towards the direction of the magnetic field. Your thumb will point in the direction of the force. If the charge is negative, the direction of the force will be opposite to the direction of your thumb.</p> <p>By only using the Right Hand Rule in</p>

			the NCS learners are less likely to get confused than when there are different rules to remember. For learners who study Physics after school, they will be well prepared to deal with vector cross products.
Electric circuits:			
<ul style="list-style-type: none"> • Relation between current, voltage and resistance (Ohm’s Law); 	<ul style="list-style-type: none"> • Determine the relationship between current, voltage and resistance at constant temperature using a simple circuit • State the difference between Ohmic and non-Ohmic conductors, and give an example of each • Solve problems using the mathematical expression of Ohm’s Law, $R=V/I$ 		<p>Link to Grade 10.</p> <p>A light bulb is a common example of a non-Ohmic conductor. Nichrome wire is an Ohmic conductor. Try to let learners do experiments in which they measure the current through, and voltage across an Ohmic and a non-Ohmic conductor. If they use nichrome wire, ensure that they only close the circuit for a very short time or else the nichrome will heat up and its resistance will change.</p>
<ul style="list-style-type: none"> • Resistance, equivalent resistance, internal resistance; 	<ul style="list-style-type: none"> • Calculate the equivalent resistance of series and parallel arrangements of resistors. • Solve problems involving current, voltage and resistance for circuits containing arrangements of resistors in series and in parallel. • State that a real battery has internal resistance • Explain why there is a difference between the emf and terminal voltage of a battery if the load (external resistance in the circuit) is comparable in size to the battery’s internal resistance • Solve circuit problems in which the internal resistance of the battery must be considered. 		<p>Some books use the term “lost volts” to refer to the difference between the emf and the terminal voltage. This is misleading. The voltage is not “lost”, it is across the internal resistance of the battery.</p> <p>The internal resistance of the battery can be treated just like another resistor in series in the circuit. The sum of the voltages across the external circuit plus the voltage across the internal resistance is equal to the emf:</p> $\varepsilon = V_{\text{load}} + V_{\text{internal resistance}}$
<ul style="list-style-type: none"> • Series, parallel networks; 	<ul style="list-style-type: none"> • Solve circuit problems involving resistors in series with parallel networks of resistors 		<p>A parallel network is an arrangement of resistors that are in parallel with each other but not with the battery. A circuit</p>

			containing one or more resistors in series with parallel network(s) is a series-parallel circuit.
• Wheatstone bridge.		<ul style="list-style-type: none"> • Given a circuit diagram, explain how the Wheatstone bridge can be used for determining resistances very accurately • Derive an expression for the unknown resistance in terms of the known resistances when the bridge circuit is balanced 	The Wheatstone Bridge enables very accurate measurements of resistance to be made by inserting an unknown resistor into a bridge circuit containing three resistors that are already accurately known, one of which is variable. The resistance of the variable resistor is changed until a galvanometer reads zero, indicating that the bridge circuit is balanced.
MATTER AND MATERIALS 25 %			
<u>Electronic properties of matter:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Conduction in semiconductors, metals, ionic liquids; • intrinsic properties and doping – properties by design; • principles of the p-n junction and the junction diode; • insulators, breakdown. 	<ul style="list-style-type: none"> • Explain how energy levels of electrons in an atom combine with those of other atoms in the formation of crystals • Explain how the resulting energy levels are more closely spaced than those in the individual atoms, forming energy bands; and thus • Explain the existence of energy bands in metal crystals as the result of superposition of energy levels • Explain and contrast the conductivity of conductors, semi-conductors and insulators using energy band theory. • Explain how insulators can break down and conduct under extreme conditions. • Explain the process of doping. • Explain how doping improves the conductivity of semi-conductors. • Compare p and n type semi-conductors • Explain how a p – n junction works. • Give everyday examples of the application of semi conductors 		This is a new topic and teachers may wish to read further on this area. But it is relevant to many aspects in modern living, such as electronics, computers, cell phones, solar cells.

<p><u>Atomic combinations: molecular structure</u></p>			
<ul style="list-style-type: none"> • A chemical bond as the net electrostatic force two atoms sharing electrons exert on each other. 	<ul style="list-style-type: none"> • Recall the role of models in science and describe the explanations of chemical bonding in this course as an application of a model • Deduce the number of valence electrons in an atom of an element • Represent atoms using Lewis diagrams • Explain, referring to diagrams showing electrostatic forces between protons and electrons, and in terms of energy considerations, why <ul style="list-style-type: none"> ○ two H atoms form an H₂ molecule, but ○ He does not form He₂ • Draw a Lewis diagram for the hydrogen molecule • Describe a chemical bond as a shared pair of electrons • Describe and apply simple rules to deduce bond formation, viz. <ul style="list-style-type: none"> ○ different atoms, each with an unpaired valence electron can share these electrons or form a chemical bond ○ different atoms with paired valence electrons called lone pairs of electrons, cannot share these four electrons and cannot form a chemical bond ○ different atoms, with unpaired valence electrons can share these electrons and form a chemical bond for each electron pair shared (multiple bond formation) ○ atoms with an incomplete complement of electrons in their valence shell can share a lone pair 		<p>Link to Grade 10 Matter and materials: The atom: the arrangement of electrons into core and valence electrons Increased stability due to lower potential energy to be used as the main reason for bonding. The mainstay of Lewis diagrams is the “rule of two” – i.e. two electrons for a bond, rather than the “octet” rule which only applies rigorously to the second period.</p>

	of electrons from another atom to form a co-ordinate or dative covalent bond (e.g. NH_4^+ , H_3O^+ ,		
<ul style="list-style-type: none"> • Chemical bonds as explained by Lewis theory and represented using Lewis diagrams. • Multiple bonds 	<p>Draw Lewis diagrams, given the formula and using electron configurations, for</p> <ul style="list-style-type: none"> • simple molecules (e.g. F_2, H_2O, NH_3, HF, OF_2, HOCl) • molecules with multiple bonds e.g. (N_2, O_2 and HCN) • molecules of compounds where atoms display variable valencies (e.g. CO, CH_4, H_2S, SO_2, SO_3) • molecules where a molecule (or molecules) donates a lone pair of electrons (Lewis base) to a molecule or ion with vacant orbitals in the valence shell (Lewis acid) to form a dative covalent bond e.g. H_3NBF_3, $\text{Cu}(\text{NH}_3)_4^{2+}$ 		
<ul style="list-style-type: none"> • Molecular shape as predicted using the Valence Shell Electron Pair Repulsion (VSEPR) theory. 		<p>Deduce the shape of</p> <ul style="list-style-type: none"> • molecules like CH_4, NH_3, H_2O, BeF_2 and BF_3 • molecules with more than four bonds like PCl_5 and SF_6, and • molecules with multiple bonds like CO_2 and SO_2 and C_2H_2 <p>from their Lewis diagrams using VSEPR theory</p>	
<ul style="list-style-type: none"> • Electro-negativity of atoms to explain the polarity of bonds.... 	<ul style="list-style-type: none"> • Explain the concepts <ul style="list-style-type: none"> ○ “electro-negativity” ○ Non-polar bond with examples, e.g. H_2 ○ Polar bond with examples e.g. H-Cl • Show polarity of bonds using partial charges <p style="text-align: center;"> δ^+ δ^- $\text{H} \text{ --- } \text{Cl}$ </p> <p style="text-align: right;">δ^+</p>		Link back to Grade 10 intermolecular forces

	<ul style="list-style-type: none"> • Explain the difference between H^+ and H • Compare the polarity of chemical bonds using a table of electronegativities • Show how polar bonds do not always lead to polar molecules 		
<ul style="list-style-type: none"> • Oxidation number of atoms in molecules to explain their relative “richness” in electrons ... 	<ul style="list-style-type: none"> • Explain the meaning of ‘oxidation number’ • Deduce oxidation numbers by assigning a -1 to the more electronegative atom in each bond and +1 to the more electropositive atom in each bond and finding the algebraic sum of the numbers assigned to a particular atom once this is done for all the bonds involving the particular atom. Atoms in non-polar bonds are assigned zero. • Assign oxidation numbers to atoms in various molecules like H_2O, CH_4, CO_2, H_2O_2, $HOCl$ • Use rules of oxidation to assign oxidation numbers to atoms in a variety of molecules and ions 		Forms a basis for electrochemistry in Grade 12
<ul style="list-style-type: none"> • Bond energy and length 	<ul style="list-style-type: none"> • Explain what is meant by bond strength • Describe ways in which atoms in a molecule can move (vibrate) relative to each other • Explain the relationship between strength of bond between two chemically bonded atoms and <ul style="list-style-type: none"> ○ the length of the bond between them ○ the size of the bonded atoms ○ the number of bonds (single, double, triple) between the atoms 		Link to potential energy diagram used to explain bonding above and point out the bond energy and bond length on that diagram

<p><u>Atomic nuclei:</u></p> <ul style="list-style-type: none"> • Nuclear structure and stability; • Radioactivity; • Ionising radiation; • Fission and fusion and their consequences; • Nucleosynthesis – the Sun and stars; • Age determination in geology and archaeology. 		<ul style="list-style-type: none"> • Explain what is meant by “binding energy” • Explain what is meant by “strong nuclear force” Link “strong nuclear force” to other non contact forces dealt with previously and explain the cohesiveness of the smaller nuclei in terms of competition between the strong nuclear force (attractive) and electrostatic repulsion forces of protons. • Compare and contrast α, β, and γ decay • Represent nuclear change using equations • Describe “half-life” and its variation between isotopes and atoms. • Describe radioactive dating. • Perform simple calculations relating half-life, time and age and the concentration of nuclides. • Compare and contrast nuclear fission and nuclear fusion. • Explain the process of nucleosynthesis that takes place in stars. 	<p>Link back to the following topics in Grade 10</p> <ul style="list-style-type: none"> • Describe a simple model for the atom that includes protons, neutrons and orbital electrons. • Explain the difference between mass number and atomic number • Explain how an element can exist in various isotopic forms. <p>LO3 possibilities Controversy over nuclear energy weapons and power and effects of radiation on the human body</p>
<p><u>Ideal gases and thermal properties:</u></p>			
<ul style="list-style-type: none"> • Motion of particles; • Kinetic theory of gases; 	<ul style="list-style-type: none"> • Describe the motion of individual molecules i.e. <ul style="list-style-type: none"> ○ collisions with each other and the walls of the container ○ molecules in a sample of gas move at different speeds • Explain the idea of ‘average speeds’ in the context of molecules of a gas • Describe an ideal gas in terms of the motion of molecules • Use kinetic theory to explain the gas laws 		<p>Integrate the teaching of this section into the treatment of the ideal gas laws below</p>

<ul style="list-style-type: none"> • Ideal gas law. 	<ul style="list-style-type: none"> • Describe the relationship between volume and pressure for a fixed amount of a gas at constant temperature (Boyle's Law) • Describe the relationship between volume and temperature for a fixed amount of a gas at constant pressure (Charles' Law) and • Describe the relationship between pressure and temperature for a fixed amount of a gas at constant temperature <ul style="list-style-type: none"> ○ practically using an example ○ by interpreting a typical table of results ○ using relevant graphs (introducing the Kelvin scale of temperature where appropriate) ○ using symbols ('α' and '$1/\alpha$') and the words 'directly proportional' and 'inversely proportional' as applicable ○ writing a relevant equation • Combine the three gas laws into the ideal gas law • Use the gas laws to solve problems • Give the conditions under which the ideal gas law does not apply to a real gas and explain why 		<p>This section is an excellent opportunity to show the relationship between macro and micro, e.g. explain the pressure volume relationship in terms of particle motions.</p> <p>It is an important section for illustrating and assessing understanding of investigative process, the relationship between theory and experiment, the importance of empirical data and mathematical modeling of relationships.</p>
<ul style="list-style-type: none"> • Temperature and heating, pressure; 	<ul style="list-style-type: none"> • Explain the temperature of a gas in terms of the average kinetic energy of the molecules of the gas • Explain the pressure exerted by a gas in terms of the collision of the molecules with the walls of the container 		
<p>CHEMICAL CHANGE 18,75 %</p>			
<p><u>Quantitative aspects of chemical change:</u></p>			
<ul style="list-style-type: none"> • Atomic weights; 	<ul style="list-style-type: none"> • Describe the mole as the SI unit for amount of substance • Relate amount of substance to 		<p><u>Refer back to atomic mass in grade 10</u></p>

	<ul style="list-style-type: none"> relative atomic mass Describe relationship between the mole and Avogadro's number Conceptualise the magnitude of Avogadro's number Describe the relationship between molar mass and relative molecular mass Calculate the molar mass of a substance given its formula 		
<ul style="list-style-type: none"> Molecular and formula weights; 	<ul style="list-style-type: none"> Reason qualitatively and proportionally the relationship between number of moles, mass and molar mass Calculate mass, molar mass and number of moles according to the relationship $n = m/M$ Determine the empirical formula for a given substance from percentage composition 		<u>Refer back to Dalton's reasoning in the history of atomic theory in Grade 10</u>
<ul style="list-style-type: none"> Determining the composition of substances; 	<ul style="list-style-type: none"> Describe practical quantitative methods for determining chemical composition Determine the percentage composition from the chemical formula of substance 		
<ul style="list-style-type: none"> Amount of substance (mole), molar volume of gases, concentration; 	<ul style="list-style-type: none"> Recall that 1 mole of gas occupies 22.4 dm³ at 0°C (273 K) and 1 atmosphere (101.3 kPa) Calculate molar concentration of a solution 		<u>Link back to gas laws above</u> <u>Express as SI units</u>
<ul style="list-style-type: none"> Stoichiometric calculations 	<ul style="list-style-type: none"> Perform stoichiometric calculations using balanced equations that may include limiting reagents 		<u>Use microscopic representations to explain how stoichiometric ratios work</u>
<u>Energy and chemical change:</u>			
<ul style="list-style-type: none"> Energy changes in reactions related to bond energy changes; 	<ul style="list-style-type: none"> Explain the concept enthalpy and its relationship to heat of reaction Define exothermic and endothermic reactions Identify that bond breaking requires energy (endothermic) and that bond 		<u>Link bond making and breaking to potential energy diagram used in bonding above</u>

	formation releases energy (exothermic)		
• Exothermic and endothermic reactions;	<ul style="list-style-type: none"> • State that $\Delta H > 0$ for endothermic reactions. • State that $\Delta H < 0$ for exothermic reactions 		
• Activation energy.	<ul style="list-style-type: none"> • Define activation energy • Explain a reaction process in terms of energy change and relate this change to bond breaking and formation and to the “activated complex”. 		
<u>Types of reaction:</u>			
• Acid-base and redox reactions;	<ul style="list-style-type: none"> • Define an acid as an H^+ donor and a base as an H^+ acceptor in reaction. • Identify conjugate acid/base pairs • Define an ampholyte • List common acids (including hydrochloric acid, nitric acid, sulfuric acid and acetic acid) and common bases (including sodium carbonate, sodium hydrogen carbonate and sodium hydroxide) by name and formula and. • Write the overall equation for simple acid-base and acid carbonate reactions and relate these to what happens at the macroscopic and microscopic level. • Determine the oxidation number from the chemical formula and electro-negativities • Identify a reduction - oxidation reaction • Describe electro-chemical reactions as involving electron transfer • Describe oxidation - reduction reactions as always involving changes in oxidation number 		<p><u>Link to oxidation numbers above In this section, care must be taken to emphasise the relationship between the symbolic (equations) and the macroscopic and microscopic representations of the reaction.</u></p>
• Substitution, addition and elimination.	<ul style="list-style-type: none"> • Describe criteria to use to classify elimination, substitution or addition 		Link to Grade 12 matter and materials:

	<p>reactions according to structural change</p> <ul style="list-style-type: none"> • Identify a reaction as an example of an elimination, substitution or addition reaction from a list of example reaction equations • List and describe elimination reactions that are important in manufacturing processes i.e. in the manufacture of alkenes, i.e. • Dehydrohalogenation of alkyl halides • Dehydration of alcohols • Naphtha and ethane cracking (SASOL) • Describe addition reactions that are important in manufacturing processes i.e. • Many polymers (addition polymerization, i.e. PVC and polystyrene) • Ethanol from ethene • Hydrogenation of vegetable oils to form margarine • Write equations for simple substitution reactions i.e. Organic reactions: • $\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}$ • $\text{CH}_3\text{Cl} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{OH} + \text{HCl}$ • Inorganic reactions: • $\text{Cu}(\text{H}_2\text{O})_4^{2+} + 4\text{Cl}^- \rightleftharpoons \text{Cu}(\text{Cl})_4^{2-} + 4\text{H}_2\text{O}$ • $\text{Cu}(\text{H}_2\text{O})_4^{2+} + \text{S}^{2-} \rightarrow \text{CuS}(\text{s}) + 4\text{H}_2\text{O}$ 		<p>substitution, addition and elimination. SASOL – polymers Link to organic chemistry in grade 12</p>
<p>CHEMICAL SYSTEMS 18,75 %</p> <p>The content and context provides opportunities to focus assessment on Learning Outcome 3, viz. evaluating</p> <ul style="list-style-type: none"> • competing knowledge claims • the impact of science on human development • the impact of science on the environment <p>It is important that teachers create the opportunities for learners to</p>			

- practice the skills they require to make such evaluations by getting them to
 - know the structure of a scientific argument and use it (“Guess-deduce-test”; Identify the proposition/hypothesis, collect evidence that supports / refutes the proposition/hypothesis, evaluate the evidence (against relevant criteria), draw conclusions (refute/accept the hypothesis) from the evidence and substantiate the conclusion using the evidence.)
 - select the relevant issues, e.g. from, say;
 - ◆ waste management,
 - ◆ use of energy (electricity),
 - ◆ use of (non-renewable) resources,
 - ◆ environmental issues ...
 - ◆ benefits to humans, positive impact on the environment say, ...
- develop the skills they require to identify (from supplied data or a text or their own knowledge) the subject content they need to substantiate their arguments, viz.
 - Use a knowledge of hazardous materials to identify risk associated with particular events/processes, e.g. manufacture and transport of fuels – fire risk, CO₂, CH₄, – greenhouse gases, CFC’s – negative impact on the ozone layer, Cl₂, Hg ... - toxic, oxides of nitrogen are produce by cars, CO₂ by cars and CO₂ and SO₂ and coal burning power stations during the generation of electricity – these gases are responsible for acid rain, smoke and ash (from furnaces) can cause lung diseases, and so on
 - Use criteria against which to evaluate the impact on humans, e.g. (health/ productivity – jobs / convenience/ technology (cell phones) / entertainment / safety / wealth creation
 - Use criteria against which to evaluate the impact on the environment (sustainable development), e.g. (global warming/ exploitation of non-renewable resources/ ozone layer / eutrophication / solid waste - land fills; nuclear waste,

Exploiting the lithosphere/Earth’s crust:	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Mining and mineral processing – gold, iron, phosphate, (South Africa’s strengths); environmental impact of these activities; 	<ul style="list-style-type: none"> • Give a brief history of humankind across the ages <ul style="list-style-type: none"> ○ linking their technology and the materials they have used to their tools and their weapons ○ referring to evidence of these activities in South Africa. • Describe the Earth’s crust as a source of the materials man uses <ul style="list-style-type: none"> ○ What is available? (the abundance of the elements on Earth) ○ Where is it found? (the uneven distribution of the elements across the atmosphere, the hydrosphere, the biosphere and the lithosphere. The uneven distribution of elements across the lithosphere ○ How is it found? (Seldom as 		Important links here to LO3 Link to aspects of chemical reactions – oxidation, factors affecting rates of reaction etc

- elements, inevitable as minerals)
- How are the precious materials recovered? (the need to mine and process the minerals by separating them from their surroundings and then processing them to recover the metals or other precious material – use terms like resources, reserves, ore, ore body)
- Describe the recovery of gold referring to
 - why it is worth mining?
 - the location of the major mining activity in South Africa?
 - the major steps in the process
 - ◆ deep level underground mining
 - ◆ separation of the ore from other rock
 - ◆ the need to crush the ore bearing rock
 - ◆ separating the finely divided gold metal in the ore by dissolving in a sodium cyanide oxygen mixture (oxidation) – simple reaction equation
 - ◆ the recovery of the gold by precipitation (Zn) (reduction) – simple reaction equation
 - ◆ smelting
- Describe the recovery of iron
 - why it is worth mining?
 - why does South Africa export iron ore?
 - the location of the major mining activity in South Africa?
 - the major steps in the process
 - ◆ open pit mining
 - ◆ separation of the ore from other rock
 - ◆ the need to crush the ore bearing rock
 - ◆ reducing the iron ore to iron in a blast furnace using coke to

	<p>produce CO</p> <ul style="list-style-type: none"> • Describe the recovery of phosphates <ul style="list-style-type: none"> ○ why it is worth mining? ○ the location of the major mining activity in South Africa? ○ the major steps in the process <ul style="list-style-type: none"> ◆ open pit mining ◆ the need to crush the ore bearing rock ◆ the insoluble calcium phosphate that is mined is made into a water soluble salt by treatment with sulphuric acid to produce “superphosphate” and with phosphoric acid to produce “triple superphosphate”. Give reaction equations for these processes. • The environmental impact of <ul style="list-style-type: none"> ○ mining operations ○ mineral recovery plants 		
<ul style="list-style-type: none"> • Energy resources and their use 	<ul style="list-style-type: none"> • Describe the recovery/processing of coal (and crude oil) <ul style="list-style-type: none"> ○ why do humans recover oil and coal (fossil fuels)? ○ the original source of oil and coal their non-renewable nature ○ the location of the major coal mining activity in South Africa? ○ the source of South Africa’s crude oil (imported from the middle east and Africa - Nigeria) ○ the major steps in the process <ul style="list-style-type: none"> ◆ open pit mining (and underground) of coal ◆ oils and natural gas from oil wells ◆ fractional distillation of natural petroleum mixtures for different purposes ◆ systematic naming of alkanes, alkenes and alkynes 		<p>Important links here to LO3 Link to organic chemistry below</p>

	<ul style="list-style-type: none"> hydrocarbons (up to 8 carbon atoms) <ul style="list-style-type: none"> ♦ cracking to increase the proportion of molecules most needed (liquid fuels) <ul style="list-style-type: none"> ○ octane rating • Describe the consequences of the current large scale burning of fossil fuels many scientists and climatologists are predicting (global warming) 		
<u>The atmosphere:</u>	Learners must be able to	Learners must be able to	
• Atmospheric chemistry;	<ul style="list-style-type: none"> • Describe the composition of the Earth's atmosphere, emphasizing how it makes life possible • Describe the reason we have weather i.e. refer to <ul style="list-style-type: none"> ○ Rain (relative humidity) ○ Wind • Describe the layered atmosphere <ul style="list-style-type: none"> ○ troposphere, ○ stratosphere, ○ mesosphere and ○ thermosphere and how these layers relate to altitudes of differing change in temperature • Describe the ionosphere and its characteristics. It <ul style="list-style-type: none"> ○ is a part of the thermosphere ○ is very thin ○ is an area in the thermosphere where the atmosphere is ionized by solar radiation ○ has a temperature that increases with height because it is warmed by the ionization process ○ is home to the auroras ○ makes radio communication possible • Explain how water is trapped beneath the stratosphere and the significance of this 		Important links here to LO3

	<ul style="list-style-type: none"> • Describe the interaction of nitrogen, oxygen and ozone molecules with high energy solar radiation in the mesosphere (see the ionosphere above) • explain the role of CFCs in the depletion of ozone and why there is anxiety about this 		
<ul style="list-style-type: none"> • Global warming and the environmental impact of population growth. 	<ul style="list-style-type: none"> • Explain that because the lithosphere contains polar molecules that absorb in the infra red region of the spectrum the world is warm which helps the Earth support life • List substances responsible for air pollution • List four of the most important greenhouse gases • Explain why there is greater production of greenhouse (pollutant) gases with an increase in human population • Explain the ‘greenhouse effect’ and why an increase in the concentration of greenhouse gases can cause global warming • Explain why climate change caused by global warming is regarded by many as so potentially harmful 		<p>Link to Gr 12 IR spectroscopy Link to polar molecules in grades 10 and 11</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

The learner is able to state, explain, interpret and evaluate scientific and technological knowledge and can apply it in everyday contexts.

Constructing and Applying Scientific Knowledge

Note: The core concepts to be learned are included under the underlined theme and form a coherent whole.

Core knowledge and concepts as in the NCS for the Physical Sciences	Core knowledge and concepts proposed for 2008 - 2010	Core knowledge and concepts proposed for the full implementation of the NCS. To be updated before implementation.	Comment and links
MECHANICS 12,5%			
<u>Motion in two dimensions:</u>	Learners must be able to,	Learners must be able to,	
<ul style="list-style-type: none"> • Projectile motion represented in words, diagrams, equations and graphs; 	<p>for vertical projectile motion (near the surface of the Earth if air friction is ignored)</p> <ul style="list-style-type: none"> • Explain that projectiles <ul style="list-style-type: none"> ○ fall freely with gravitational acceleration 'g' ○ accelerate downwards with a constant acceleration whether the projectile is moving upward or downward ○ have zero velocity at their greatest height ○ take the same the time to reach their greatest height from the point of upward launch as the time they take to fall back to the point of launch ○ can have their motion described by a single set of equations for the upward and downward motion • Use equations of motion, e.g. to determine <ul style="list-style-type: none"> ○ the greatest height reached given the velocity with which the projectile is launched upward (initial velocity) ○ the time at which a projectile is at a particular height given its initial velocity ○ the height relative to the ground of the position of a projectile shot vertically upward at launch, given 	<p>for two dimensional projectile motion (near the surface of the Earth if air friction is ignored)</p> <ul style="list-style-type: none"> • calculate the horizontal and vertical components of a projectile launched at an angle, θ, to the horizontal • Use the equations of motion to calculate displacement and velocity for the vertical component of projectile motion, setting the acceleration equal to g • use the equations of motion to calculate displacement and velocity for the horizontal component of projectile motion, setting the acceleration equal to zero • Use the equations of motion for the horizontal and vertical components of projectile motion to calculate the time taken for the motion. • Calculate the initial and final velocity from the horizontal and vertical components, i.e. calculate the magnitude and angle relative to the horizontal. • 	<p>Link to Grade 10 motion in one dimension.</p> <p>Link to Grade 11 Newton's second Law and the Law of Universal Gravitation</p> <p>The equations of motion are identical to the equations introduced in Grade 10. Do not derive a special set of equations – use the general equations and set $a=g$ for the vertical component of the motion and $a=0$ for the horizontal component. Be sure to select positive and negative directions, and make sure that the signs of the displacement, velocity and acceleration are consistent with the directions you choose. The acceleration of gravity always points downwards.</p> <p>When the velocity has a horizontal and a vertical component, the magnitude of the velocity can be obtained using Pythagoras theorem, $v = \sqrt{v_i^2 + v_f^2}$ and the angle of</p>

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	<p>the time for the projectile to reach the ground</p> <ul style="list-style-type: none"> • Draw position vs time (x vs t), velocity vs time (v vs t) and acceleration vs time (a vs t) graphs for projectile motion • Give equations for position versus time and velocity versus time for the graphs of motion of particular projectiles and vice versa. • Given x vs t, v vs t or a vs t graphs <ul style="list-style-type: none"> ○ determine position, displacement, velocity or acceleration at any time t ○ describe the motion of the object e.g. graphs showing a ball, <ul style="list-style-type: none"> ♦ bouncing, ♦ thrown vertically upwards ♦ thrown vertically downward, and so on 		<p>elevation from $\theta = \tan^{-1} \frac{v_y}{v_x}$</p>
<ul style="list-style-type: none"> • Conservation of momentum in 2D; 	<ul style="list-style-type: none"> • Know that the momentum of a system is conserved when no external forces act on it • Calculate x and y components of momentum • Solve problems involving conservation of momentum in both the x direction and the y direction • Know that an external force causes the momentum to change. The impulse delivered by the force is $F\Delta t = \Delta p$. • Solve problems involving impulse and momentum when the applied force is in the horizontal or vertical direction. • Distinguish between elastic and inelastic collisions 	<ul style="list-style-type: none"> • Solve problems involving impulse and momentum when the applied force is neither horizontal nor vertical but is at an angle • Solve problems involving elastic and inelastic collisions for objects moving at an angle other than 90° to each other. • 	<p>Link to Grade 11 conservation of momentum. As before, use the equation:</p> $p_i = p_f$ <p>except now use one equation for components in the x direction and one equation for components in the y direction</p> <p>Link to grade 11 impulse.</p> <p>Link to Grade 10 “kinetic energy”</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

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Constructing and Applying Scientific Knowledge

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	inelastic collisions. <ul style="list-style-type: none"> Solve problems involving elastic and inelastic collisions for objects moving parallel or at right angles to each other. 		Traffic accidents provide a very good context for studying inelastic collisions.
<ul style="list-style-type: none"> Frames of reference. 	<ul style="list-style-type: none"> Define a frame of reference Give examples of the importance of specifying the frame of reference Define relative velocity Specify the velocity of an object relative to different frames of reference, e.g. for a person walking inside a train give the velocity relative to the train and relative to the ground. Use vectors to find the velocity of an object that moves relative to something else that is itself moving, e.g. if the velocity of a bird relative to the air is \vec{v}_{ba} and of the air relative to the ground is \vec{v}_{ag} then the velocity of the bird relative to the ground is $\vec{v}_{bg} = \vec{v}_{ba} + \vec{v}_{ag}$ 		Link to Grade 10 “frames of reference in one dimension”
<u>Work, power and energy:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> When a force exerted on an object causes it to move, work is done on the object (except if the force and displacement are at right angles to each other); 	<ul style="list-style-type: none"> Define the work done on an object by a force Give examples of when an applied force does and does not do work on an object Calculate the work done by an object when a force F applied at angle θ to the direction of motion causes the object to move a distance d, using $W = Fd \cos \theta$ 		Link to Grade 11 forces. Stress the difference between the everyday use of the word “work” and the physics use. Only the component of the applied force that is parallel to the motion does work on an object. So, for example, a person holding up a heavy book

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

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Core knowledge and concepts as in the NCS for the Physical Sciences	Core knowledge and concepts proposed for 2008 - 2010	Core knowledge and concepts proposed for the full implementation of the NCS. To be updated before implementation.	Comment and links
			does no work on the book.
<ul style="list-style-type: none"> • The work done by an external force on an object/system equals the change in kinetic energy of the object/system; 	<ul style="list-style-type: none"> • Know that an object with larger potential energy has a greater capacity to do work • Solve problems using the work energy theorem, i.e. the work done on an object is equal to the change in its kinetic energy: $W = \Delta E_k = E_{kf} - E_{ki}$ 		<p>Link to grade 10: conservation of energy</p> <p>Give examples showing that objects with greater potential energy can do more work, e.g. a hammer dropped from a greater height can do more work than one dropped from a lower height.</p> <p>NOTE: a force only does work on an object if it stays in contact with the object. For example, a person pushing a trolley does work on the trolley, but the road does no work on the tyres of a car if they turn without slipping (the force is not applied over any distance because a different piece of tyre touches the road every instant).</p>
<ul style="list-style-type: none"> • Power (rate at which work is done). 	<ul style="list-style-type: none"> • Define power as the rate at which work is done or energy is expended • Calculate the power involved when work is done • If a force causes an object to move at a constant velocity, calculate the power using $P=Fv$. • Apply to real life examples, e.g. the minimum power required of an electric motor to pump water from a borehole of 		

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

The learner is able to state, explain, interpret and evaluate scientific and technological knowledge and can apply it in everyday contexts. Constructing and Applying Scientific Knowledge Note: The core concepts to be learned are included under the underlined theme and form a coherent whole.			
Core knowledge and concepts as in the NCS for the Physical Sciences	Core knowledge and concepts proposed for 2008 - 2010	Core knowledge and concepts proposed for the full implementation of the NCS. To be updated before implementation.	Comment and links
	a particular depth at a particular rate, the power of different kinds of cars operating under different conditions		
WAVES, SOUND AND LIGHT 12,5%			
<u>Doppler Effect (source moves relative to observer):</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • With sound and ultrasound; 	<ul style="list-style-type: none"> • State what the Doppler Effect is for sound and give everyday examples. • Explain why a sound increases in pitch when the source of the sound travels towards a listener and decreases in pitch when it travels away. • Use the equation $f_L = \frac{v \pm v_L}{v \pm v_S} f_S$ to calculate the frequency of sound detected by a listener (L) when either the listener or the source (S) is moving. <ul style="list-style-type: none"> ○ Describe applications of the Doppler Effect with ultrasound waves in medicine, e.g. to measure the rate of blood flow or the heartbeat of a foetus in the womb. 		<p>Link to Grade 11, pitch of sounds.</p> <p>Link to reference frames (relative motion) in Grade 12 mechanics.</p>
<ul style="list-style-type: none"> • With light – red shifts in the universe (evidence for the expanding universe). 	<ul style="list-style-type: none"> • State that light emitted from many stars is shifted toward the red, or longer wavelength/lower frequency, end of the spectrum. • Apply the Doppler effect to these “redshifts” to conclude that most stars are moving away from Earth and therefore the universe is expanding 		<p>Link to Grade 12 Electricity and Magnetism, Electromagnetic Spectrum. The red end of the spectrum corresponds to lower frequency and the blue end to higher frequency light.</p> <p>Link to Grade 12 Matter and Materials, emission spectra and</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

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Constructing and Applying Scientific Knowledge

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Core knowledge and concepts as in the NCS for the Physical Sciences	Core knowledge and concepts proposed for 2008 - 2010	Core knowledge and concepts proposed for the full implementation of the NCS. To be updated before implementation.	Comment and links
			discuss the fact that stars emit light of frequencies that are determined by their composition.
<u>Colour:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> Relationship to wavelength and frequency; 	<ul style="list-style-type: none"> Know that each colour is associated with light of a particular frequency Use the equation $c=f\lambda$ to calculate the wavelength of light of a given frequency and vice versa. Explain why when white light is refracted through a prism it separates into light of different colours by referring to the difference in the speed of light of different frequencies in glass 		<p>Link to Grade 10 and 11, wavelength and frequency, refraction</p> <p>Link to Grade 12 Electricity and Magnetism, Electromagnetic Spectrum</p>
<ul style="list-style-type: none"> Pigments, paints; 	<ul style="list-style-type: none"> Explain what determines the colour of an opaque object and of a transparent object when illuminated with white light Explain that pigments give an object its colour by absorbing certain frequencies of light and reflecting other frequencies. For example, a red pigment reflects red light and absorbs cyan (blue + green). Use the concept of colour subtraction to predict how paints can create any colour by using varying amounts of the three primary colours of paint (cyan, magenta, yellow). 		<p>An opaque object reflects light of some frequencies and absorbs other frequencies. Its colour is determined by the light it reflects.</p> <p>A transparent object transmits light of some frequencies and absorbs others. Its colour is determined by the light it transmits.</p>
<ul style="list-style-type: none"> Addition and subtraction of light. 	<ul style="list-style-type: none"> Know that the superposition of red, blue and green light produces white light. All other colours are produced by different combinations of these colours. 		<p>Addition of light provides another context to apply the concept of superposition.</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

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Constructing and Applying Scientific Knowledge

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	<p>Red, blue and green are therefore the additive primary colours.</p> <ul style="list-style-type: none"> • Use colour addition to make predictions about the colours produced when different coloured light is mixed. • Describe the ability of the eye to perceive any colour due to its three types of cones (in the retina) that are sensitive to red, green and blue light, respectively. • Explain why a TV screen comprises red, green and blue dots • Know that the subtractive primary colours are magenta, yellow and cyan, and explain how these colours are obtained. • Define complementary colours as two colours which add together to give white • Determine the complementary colours for red, green and blue. 		<p>Subtractive primary colours are obtained by subtracting one of the three additive primary colours: Magenta = Red + Blue Yellow = Red + Green Cyan = Blue + Green</p> <p>The complementary colours are: Red and Cyan Green and Magenta Blue and Yellow.</p>
<u>2D and 3D wavefronts:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Diffraction; 	<ul style="list-style-type: none"> • Define a wavefront as an imaginary line that connects waves that are in phase (e.g. all at the crest of their cycle). • State Huygen's principle. • Define diffraction as the ability of a wave to spread out in wavefronts as they pass through a small aperture or around a sharp edge. • Apply Huygen's principle to explain diffraction qualitatively. Light and dark 		<p>It is very helpful to use water waves in a ripple tank to demonstrate diffraction and interference.</p>

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

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	<p>areas can be described in terms of constructive and destructive interference of secondary wavelets.</p> <ul style="list-style-type: none"> • Sketch the diffraction pattern for a single slit. • Use the approximation $\theta = \frac{m\lambda}{a}$ for a slit of width a to calculate the position (angle from the horizontal) of the dark bands in a single slit diffraction pattern, where $m = \pm 1, \pm 2, \pm 3, \dots$ 		
<ul style="list-style-type: none"> • Interference (special kind of superposition); 	<ul style="list-style-type: none"> • Define interference as when two waves pass through the same region of space at the same time, resulting in superposition of waves. • Explain the concepts of constructive and destructive interference. • Predict areas of constructive and destructive interference from a diagram / source material. • Investigate the interference of waves on the surface of water from two coherent sources, vibrating in phase. • Draw an interference pattern marking nodal lines and noting positions of maximum interference. 		
<ul style="list-style-type: none"> • Shock waves, sonic boom. • diffraction 	<ul style="list-style-type: none"> • Describe, with the aid of a diagram, the formation of a shock wave as an example of interference of wavefronts formed when the object emitting waves is traveling faster than the speed of the waves in the medium 	<ul style="list-style-type: none"> • Show that the half-angle of the cone of the sonic boom may be calculated from $v_w = v_s \sin \theta$. 	

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

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Constructing and Applying Scientific Knowledge

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	<ul style="list-style-type: none"> • Define the terms: <ul style="list-style-type: none"> ○ subsonic ○ supersonic ○ “Mach” number • Explain the phenomenon of shockwaves in terms of the Doppler Effect and constructive interference of sound waves. • State that a “sonic boom” is the sound heard by an observer as a shockwave passes. 		
<u>Wave nature of matter:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • de Broglie wavelength; 	<ul style="list-style-type: none"> • Derive the formula for calculating the de Broglie wavelength. $\lambda = \frac{h}{mv}$ • Show that a wavelength calculated for something like a moving cricket ball is so small as to be meaningless but that for a fast-moving electron, the wavelength is such as to expect it to undergo diffraction in the right circumstances. • Calculate the de Broglie wavelength for electrons of varying speeds. • Relate the de Broglie wavelength of the electron to wavelengths within the electromagnetic spectrum. i.e. they are much smaller than that of visible light. 		Learners should already be able to: <ul style="list-style-type: none"> • Describe structure of an atom. • Apply the concept of momentum. • Describe the electromagnetic spectrum. • Describe the dual nature of electromagnetic radiation. • Describe that light is transmitted as tiny particles known as photons.

Core knowledge and concepts (Learning Outcome 2 - Grade 12)

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Constructing and Applying Scientific Knowledge

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<ul style="list-style-type: none"> • Electron microscope 	<ul style="list-style-type: none"> • Compare, by means of a simple diagram, the principle of operation of an electron microscope with an optical microscope in terms of the specimen, focusing and image formation. 	<ul style="list-style-type: none"> • Explain that electron microscopes, both transmission (TEM) and scanning (SEM), produce images based on the wave properties of electrons, just as light microscopes produce images based on the wave properties of light. • State that extremely small de Broglie wavelengths of high-speed electrons permit imaging with a high resolution and magnification, whereas the magnification of a light microscope is limited by the wavelength of light. • Compare the internal operating mechanisms of the light microscope with the transmission electron microscope. <p>i.e.</p>			
		<p>source</p>		<p>Light Microscope</p>	<p>Transmission Electron Microscope (TEM)</p>
				<p>visible light transmitted through specimen</p>	<p>invisible beam of electrons transmitted through specimen</p>

		<table border="1"> <tr> <td>focusing mechanism</td> <td>optical lenses</td> <td>magnetic field of solenoid (acts like a converging lens for electrons)</td> </tr> <tr> <td>imaging</td> <td>the eye</td> <td>fluorescent screen or photographic plate</td> </tr> <tr> <td colspan="3"> <ul style="list-style-type: none"> Discuss the differences between the operation of the transmission electron microscope (TEM) and the scanning electron microscope (SEM). </td> </tr> </table>	focusing mechanism	optical lenses	magnetic field of solenoid (acts like a converging lens for electrons)	imaging	the eye	fluorescent screen or photographic plate	<ul style="list-style-type: none"> Discuss the differences between the operation of the transmission electron microscope (TEM) and the scanning electron microscope (SEM). 		
focusing mechanism	optical lenses	magnetic field of solenoid (acts like a converging lens for electrons)									
imaging	the eye	fluorescent screen or photographic plate									
<ul style="list-style-type: none"> Discuss the differences between the operation of the transmission electron microscope (TEM) and the scanning electron microscope (SEM). 											
ELECTRICITY AND MAGNETISM 12,5%											
Electrodynamics:	Learners must be able to	Learners must be able to									
<ul style="list-style-type: none"> Electrical machines (generators, motors); 	<ul style="list-style-type: none"> State that generators convert mechanical energy to electrical energy and motors convert electrical energy to mechanical energy Use Faraday's Law to explain why a current is induced in a coil that is rotated in a magnetic field. Use words and pictures to explain the basic principle of an AC generator (alternator) in which a coil is mechanically rotated in a magnetic field Use words and pictures to explain how a DC generator works and how it differs from an AC generator. Explain why a current-carrying coil placed in a magnetic field (but not parallel to the field) will turn by referring to the force exerted on moving charges by a magnetic field and the torque on the coil Use words and pictures to explain the basic principle of an electric motor. Give examples of the use of AC and DC generators. Give examples of the use of motors. 	<p>The basic principles of operation for a motor and a generator are the same, except that a motor converts electrical energy into mechanical energy and a generator converts mechanical energy into electrical energy. Both motors and generators can be explained in terms of a coil that rotates in a magnetic field. In a generator the coil is attached to an external circuit and mechanically turned, resulting in a changing flux that induces an emf (refer to Grade 11). In an AC generator the two ends of the coil are attached to a slip ring that makes contact with brushes as it turns. The direction of the current changes with every half turn of the coil. A DC generator is constructed the same way as an AC generator except that the slip ring is split into two pieces, called a commutator, so the current in the external circuit does not change direction. In a motor, a current-carrying coil is in a magnetic field</p>									

			carrying coil in a magnetic field experiences a force on both sides of the coil (refer to Grade 11), creating a torque (refer to Grade 11 Mechanics), which makes it turn.
• Alternating current;	<ul style="list-style-type: none"> • Explain the advantages of alternating current • Write expressions for the current and voltage in an AC circuit • Define the rms (root mean square) values for current and voltage as $I_{rms} = \frac{I_{max}}{\sqrt{2}} \text{ and } V_{rms} = \frac{V_{max}}{\sqrt{2}}$ respectively, and explain why these values are useful. • Draw a graph of voltage vs time and current vs time for an AC circuit. 		The main advantage to AC is that the voltage can be changed using transformers. That means that the voltage can be stepped up at power stations to a very high voltage so that electrical energy can be transmitted along power lines at low current and therefore experience low energy loss due to heating. The voltage can then be stepped down for use in buildings, street lights, and so forth.
• Capacitance and inductance		<ul style="list-style-type: none"> • Revise capacitance from Grade 11 • Define the reactance of a capacitor as $X_C = \frac{1}{2\pi fC}$ where reactance in an AC circuit plays a similar role to resistance in a DC circuit • Explain that a capacitor blocks the flow of DC and low frequency AC but allows the flow of high frequency AC because its reactance decreases with increasing frequency. • Describe an inductor as a solenoid, and inductance, L, as the ability of the solenoid to create an induced voltage when a changing current passes through it • Define the reactance of an inductor as $X_L = 2\pi fL$ • Calculate the inductance of a solenoid using the expression 	

		$L = \frac{\mu_o AN^2}{l}$, where inductance is measured in henry (H). <ul style="list-style-type: none"> • Explain that an inductor blocks high frequency AC because its reactance increases with frequency, but allows low frequency AC and DC to pass. ○ 	
Electronics:	Learners must be able to	Learners must be able to	
• Capacitive and inductive circuits;		<ul style="list-style-type: none"> ▪ Perform calculations on capacitive circuits using the formula: $V^2 = I^2(R^2 + X_C^2)$ ▪ Understand that in a circuit containing both resistive and reactive components, the ratio $\frac{V}{I}$ is neither pure resistance nor pure reactance. The ratio is called <i>impedance</i>. $Z = \sqrt{(R^2 + X_C^2)}$ where Z: impedance (Ω) ▪ Understand that any coil has inductance, but also resistance. So a coil can be considered as a resistance and an inductance in series. The impedance of an inductor is given by: $Z = \sqrt{(R^2 + X_L^2)}$ 	
• Filters and signal tuning;		<ul style="list-style-type: none"> • Describe how capacitors and inductors can be used as filters for currents of certain frequencies • For a circuit containing both an inductor and a capacitor (LRC circuit), calculate the impedance using the expression $Z = \sqrt{R^2 + (X_L - X_C)^2}$ • State the relationship between the phase of the voltages across an inductor, a resistor and a capacitor in an LRC circuit. • Explain what is meant by resonance and calculate the resonant frequency of an 	

		<p>LRC circuit</p> <ul style="list-style-type: none"> • Explain how LRC circuits are used for signal tuning and calculate values of relevant quantities needed to receive specific frequencies 	
<ul style="list-style-type: none"> • Active circuit elements, diode, light emitting diode (LED) and field effect transistor (FET), operational amplifier; 	<ul style="list-style-type: none"> • Describe a diode as a device used in electronics that allows current to flow in one direction only. • Explain that a diode consists of two doped semi-conductors joined together so that the resistance is low when connected one way and very high the other way. • Describe the LED as a diode that emits light when conducting. • Give examples of the use LEDs in everyday life 	<ul style="list-style-type: none"> • Describe the essential difference between the working of a transistor as a current amplifier and the FET as a voltage amplifier. • Describe the structure of an FET and give the meanings of the terms source, drain and gate. • Describe how the depletion layer forms and that its width is controlled by a negative voltage applied to the gate. • Describe that an output voltage of an FET is equal to the input voltage multiplied by a constant. • Explain that for mathematical operations such as multiplication and addition, a special amplifier is required. Such a device is an operational amplifier or op-amp. • Use the 741 op-amp as an example and explain that it has two input terminals called the inverting and non-inverting inputs. <p>Explain the need for a trimming potentiometer when using an op-amp.</p>	
<ul style="list-style-type: none"> • principles of digital electronics – logical gates, 		<ul style="list-style-type: none"> • Describe digital electronics as all-pervasive in modern technology: it is the ability to encode information with digital symbols that has made information processing the most important of modern technologies. • State that in digital electronics, two symbols are used: 1, which means “high” and 0, which means “low” (binary system). • Describe a logic gate as a device made 	

		<p>with groups of transistors on a single chip called an integrated circuit (IC).</p> <ul style="list-style-type: none"> • Recall the five main types of logic gates: i.e. NOT; AND; OR; NAND; NOR. • Illustrate the correct symbol for each logic gate. • Compile the relevant truth table for each of the five logic gates. • Perform simple problem-solving exercises with two gates joined together to find the equivalent gate using truth tables. <p>Describe and explain how to use transistors to make a circuit that can count in the binary system.</p>	
• Counting circuits.		<ul style="list-style-type: none"> • State that the basis of all computer memories is the bistable or flip-flop. • Demonstrate and explain that two NOR gates in series form a flip-flop and can remember one bit of information; • State that one bit is short for binary digit. • Demonstrate that all numbers can be represented as binary numbers and be expressed in terms of 0s and 1s. • Show that counting circuits use flip-flops to “divide by two”. • Describe that the modulo of a counter is the number of pulses needed to reset its output states to 0. For example, a modulo counter counts up to seven then resets itself to zero. • Describe and explain a modulo 8 counter to allow counting from 0 (=000) to 7 (=111) using three flip-flops. • Explain that computers use millions of NOR gates to count. <p>Describe how to use NOR gates to make a circuit that can count</p>	
	Learners must be able to	Learners must be able to	

Electromagnetic radiation:			
<ul style="list-style-type: none"> • Dual (particle/wave) nature of EM radiation; 	<ul style="list-style-type: none"> • Explain that some aspects of the behaviour of EM radiation can best be explained using a wave model and some aspects can best be explained using a particle model 		<p>Link to Grade 12 Matter and Materials, photoelectric effect</p>
<ul style="list-style-type: none"> • Nature of an EM-wave as mutual induction of oscillating magnetic/electric fields; 	<ul style="list-style-type: none"> • Describe the source of electromagnetic waves as an accelerating charge • Use words and diagrams to explain how an EM wave propagates when an electric field oscillating in one plane produces a magnetic field oscillating in a plane at right angles to it, which produces an oscillating electric field, and so on • State that these mutually regenerating fields travel through space at a constant speed of 3×10^8 m/s, represented by c. 		<p>Mention that unlike sound waves, EM waves do not need a medium to travel through</p>
<ul style="list-style-type: none"> • EM spectrum; 	<ul style="list-style-type: none"> • Given a list of different types of EM radiation, arrange them in order of frequency or wavelength. • Given the wavelength of EM waves, calculate the frequency and vice versa, using the equation $c=f\lambda$. • Give an example of the use of each type of EM radiation, i.e. gamma rays, X-rays, ultraviolet light, visible light, infrared, microwave and radio and TV waves. 		<p>Link to Grade 10 Waves, Sound and Light</p>
<ul style="list-style-type: none"> • Nature of EM as particle – energy of a photon related to frequency and wavelength; 	<ul style="list-style-type: none"> • Calculate the energy of a photon using $E = hf = hc/\lambda$ 		
<ul style="list-style-type: none"> • penetrating ability. 	<ul style="list-style-type: none"> • Indicate the penetrating ability of the different kinds of EM radiation and relate it to energy of the radiation. • Describe the dangers of gamma rays, X-rays and the damaging effect of ultraviolet radiation on skin 		<p>Link to Grade 11 Matter and Materials, atomic nuclei</p>

MATTER AND MATERIALS 25 %			
<u>Optical phenomena and properties of materials:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Transmission and scattering of light; 	Explain the interaction of uv and visible radiation with: metals: reflect (absorb and re-emit) in terms of the interaction with electromagnetic radiation Explain why the sky is blue	explain the interaction of uv and visible radiation with: <ul style="list-style-type: none"> • non-metals – transparent (glass,) • non metals - coloured (graphite, chlorophyll, dyes e.g. cyanine, β-carotene, lycopene) in terms of the interaction with electromagnetic radiation	Link the interaction of matter with light to the electronic properties of matter (grade 11 electrical conduction)
<ul style="list-style-type: none"> • Photoelectric effect. 	<ul style="list-style-type: none"> • Describe the photoelectric effect as the process that occurs when light shines on a metal and it ejects an electron • Give the significance of the photoelectric effect: <ul style="list-style-type: none"> ○ it establishes the quantum theory ○ it illustrates the particle nature of light 		Link the interaction of matter with light to the electronic properties of matter (grade 11 electrical conduction) This is a good opportunity to show how certain models are applicable in one case, but not in another, so the link needs to be made here to the dual nature of electromagnetic radiation in the grade 12 section on electricity and magnetism. Also link to de Broglie wavelength in the waves sound and light , grade 12.
<ul style="list-style-type: none"> • Emission and absorption spectra; 	<ul style="list-style-type: none"> • explain the source of atomic emission spectra (cf discharge tubes) and their unique relationship to each element • relate the lines on the atomic spectrum to electron transitions between energy levels • explain the difference between of atomic absorption and emission spectra • use $E = hf$ to determine the energy of photons of uv and visible light of varying colours 	<ul style="list-style-type: none"> • relate colour of non-metals to conjugated double bonds (chlorophyll and β-carotene) • infra red spectra to vibrations of polar bonds within molecules (CO_2; H_2O) non-absorption by O_2 and N_2 	Link to the balance required for the Earth to maintain a constant average temperature and to global warming and greenhouse gases in grade 10 chemical systems.. Also link to atmospheric chemistry and the making and breaking of bonds by solar radiation. Link to red and blue shift in Doppler effect in waves sound and light section. Link to colour section in waves

	<ul style="list-style-type: none"> • relate uv visible light to atomic absorption spectra 		<p>sound and light - pigments and paints, grade 12.</p> <p>Link to quantization of energy levels under the atom in matter and materials Grade 10</p>
<ul style="list-style-type: none"> • Lasers; 	<ul style="list-style-type: none"> • Explain and contrast the concepts of spontaneous emission of radiation and stimulated emission of radiation. • State that Lasers emit light which is monochromatic and in phase. • Explain – in simple terms – how a laser works. Include concepts of a meta-stable state, population inversion and the consequence of decay of some atoms from the meta-stable state and their subsequent stimulation of other excited atoms to emit photons in phase with this emission. • Recognise that the materials used for Lasers all allow a population inversion to be set up and that materials which have been used include synthetic ruby, a mixture of helium and neon (He-Ne lasers) and various semiconductors. • Describe the arrangement of the Laser cavity and its effects of: <ul style="list-style-type: none"> ○ Increasing amplification ○ Concentrating beam intensity ○ Improving the spectral purity of the beam (Narrowing the frequency of the beam.) • Identify some advantages of Laser applications in respect of: <ul style="list-style-type: none"> ○ Barcodes ○ Laser communication and Fibre-optics ○ Medical Lasers ○ Laser printers 		

	o Optical storage media		
Organic molecules:	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> Organic molecular structures – functional groups, saturated and unsaturated structures, isomers; 	<ul style="list-style-type: none"> give, condensed structural, structural and shorthand formulae for alkanes and compounds containing the following functional groups: double carbon-carbon bonds (including conjugated double bonds), triple carbon-carbon bonds, alkyl halides, alcohols, carboxylic acids, esters, amines, amides, ketone, arene (benzene ring) explain the terms saturated, unsaturated and isomer identify compounds that are saturated, unsaturated and are isomers (up to 8 carbon atoms) 		<p>Links to Gr 11 multiple bonds (matter and materials) Gr 12 polymers biological macro-molecules (matter and materials) and chemical systems To <u>recognize structures</u> of polymers and biological macro-molecules learners will need to work with compounds containing an unlimited number of carbon atoms. The functional groups listed are required for the <u>recognition</u> of common polymers and biological macro-molecules</p>
<ul style="list-style-type: none"> Systematic naming and formulae, structure physical property relationships; 	<p>Give the systematic name given the formula, and vice versa, for compounds with the functional groups listed under Gr 12 Organic Molecules above, up to a maximum of 8 carbon atoms</p> <p>Recognize and apply to particular examples the relationship between melting points, boiling points, vapour pressure, viscosity and intermolecular forces (hydrogen bonding, Van der Waals forces including dispersion or London forces number and type of functional group, chain length, branched chains)</p>		<p>Link to grade 10 matter and materials intermolecular forces.</p>
<ul style="list-style-type: none"> Substitution, addition and elimination reactions. 	<p>Unsaturated compounds undergo addition reactions to form saturated compounds e.g. $\text{CH}_2=\text{CH}_2 + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}-\text{CH}_2\text{Cl}$ Saturated compounds undergo elimination reactions to form unsaturated compounds e.g. $\text{CH}_2\text{Cl}-\text{CH}_2\text{Cl} \rightarrow \text{CH}_2=\text{CHCl} +$</p>		<p>Link to grade 11 Chemical Change: Types of reaction addition and elimination reactions grade 12 Chemical Systems: SASOL fuels (cracking) - elimination grade 12 Chemical systems:</p>

	<p>HCl</p> <p>Two types of saturated structure can be inter-converted by substitution e.g.</p> $(\text{CH}_3)_3\text{OH} + \text{HBr} \rightarrow (\text{CH}_3)_3\text{Br} + \text{H}_2\text{O}$ $(\text{CH}_3)_3\text{Br} + \text{KOH} \rightarrow (\text{CH}_3)_3\text{OH} + \text{KBr}$		polymerization addition
<u>Mechanical properties:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Hooke's Law, stress-strain, ductile and brittle materials; 	<ul style="list-style-type: none"> • Appreciate that deformation is caused by a force that can either be compressive or tensile when applied in 1 plane • Describe behaviour of a spring in terms of the relationship between applied force and extension of a spring [Hooke's Law]. • Demonstrate an understanding of the similarities and differences between force-extension graphs for typical ductile, brittle and polymeric materials • Recognize the point of ultimate tensile stress and the point beyond which permanent deformation takes place (elastic limit) and the point beyond which Hooke's Law is no longer obeyed (Limit of proportionality) 		
<ul style="list-style-type: none"> • Elasticity, plasticity, fracture, creep (descriptive); 	<ul style="list-style-type: none"> • Compare and contrast elastic and plastic deformation • Compare and contrast creep and fracture as modes of failure in material. 		
<ul style="list-style-type: none"> • Fracture, strength of materials. 	<ul style="list-style-type: none"> • Compare and contrast the brittle and ductile modes of failure • Explain the behaviour and properties of materials by using an understanding of structure of 		

	<p>materials. Terms should include vacancies, dislocations, impurities, and terms like grain boundaries and slip planes</p> <ul style="list-style-type: none"> • Understand that a material's mechanical properties can be described in terms of ductile, malleable, tough and elastic. • Demonstrate understanding of how a material's mechanical properties can be controlled by cold working, annealing, tempering, and introduction of impurities, alloying and sintering. 		
<u>Organic macromolecules:</u>	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Plastics and polymers – thermoplastic and thermoset 	<ul style="list-style-type: none"> • Describe the term polymer using a mind map (or concept map) that includes terms that refer to <ul style="list-style-type: none"> ○ their microscopic structure like macromolecule, chain, monomer, heterogeneous mixture, functional groups, ... ○ their macroscopic properties like resistance to chemicals, thermal and electrical insulators, (varying) low density and varying (great) strength and versatility (foamed, molded, extruded into fibre, ...) ○ their uses like packaging; fibres for clothing; tyres; adhesives; products from thin film to plastic 'crocery and cutlery' even furniture, sports equipment, automobile parts, floor coverings, paint, ... ○ their commercial importance by giving the quantities of the most commercially important polymers produced annually, ○ the typical length (size) and molecular mass of these 		Maybe overload here – identify sections for examination

	<p>macromolecules relative to each other</p> <ul style="list-style-type: none"> ○ examples ● Illustrate the reactions to produce polymers by addition reaction using the radical polymerization of ethene to produce polythene. Refer to initiation, propagation and termination. ● Illustrate the reactions to produce polymers by condensation reaction with the reactions to produce NYLON and polyester. ● Identify the monomer used to produce a polymer from the structural formula of a section of a chain. ● Identify a polymer as the product of an addition or condensation polymerization reaction, from its structural formula. ● Draw the structural formula of an addition polymer that could be produced from monomers containing one carbon–carbon double bond, given the structural formula(e) of the monomer(s), or vice versa. ● Identify the ester link in a polyester and the amide link in a polyamide. ● Draw the structural formula of the polyester or polyamide polymers that could be produced from monomers, given the structural formula(e) of the monomer(s), or vice versa. ● Describe the effects of heating on thermoplastic and thermoset polymers, and the consequent difference in ease of recycling. ● Describe the advantages and disadvantages of the use of 		
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	<p>materials composed of polymers and fillers. (Adapted from SENIOR SECONDARY ASSESSMENT BOARD OF SOUTH AUSTRALIA, STAGE 2 CHEMISTRY, WEEK 27 ASSIGNMENT, Subtopic 6.1: Polymers)</p>		
<p>• Biological macromolecules – structure, properties, function.</p>		<p>Carbohydrates</p> <ul style="list-style-type: none"> ♦ Describe photosynthesis as a reaction that produces carbohydrates (glucose) ♦ Describe respiration as the process during which glucose reacts with oxygen to form carbon dioxide and water with the simultaneous transfer of energy to cells. ♦ Explain the role of the glucose molecule as a store of solar energy ♦ Draw the structure of glucose in open chain form and cyclic form ♦ Describe, using structural formulae, the polymerisation of glucose in plants to form starch and cellulose <p>Proteins</p> <ul style="list-style-type: none"> ♦ Given a structural formula of an amino acid, identify the carboxyl group, the amino group and the carbon side chain, R, ♦ Draw the zwitterions structure of amino acids to show regions of positive and negative charge. ♦ Describe how the side chain of amino acids determines the hydrophilic and hydrophobic properties of the molecule. ♦ Draw the structure of glycine, alanine and serine ♦ Illustrate how amino acids combine to form a peptide using combinations of glycine, alanine and serine. ♦ Describe a peptide bond ♦ Identify the amino acid (monomer) used to produce a protein (polymer) from the structural formula of a section of a chain. 	<p>Proteins are essential for life and are synthesized in cells from the DNA molecule. Learners are introduced to simple biological monomers when studying the structure of amino acids. The properties of different amino acids are directly related to their structure.</p> <p>Amino acids combined to form biological polymers – proteins. There are only 20 amino acids but millions of different proteins. The sequence of the amino acids in a protein gives it its particular properties. To illustrate this variety we have chosen three simple amino acids.</p> <p>The protein is not a linear molecule. The primary structure forms as amino acids are linked by peptide bonds. The secondary structure forms as proteins wrap around each other in a helix. Hydrogen bonding is crucial in these giant biological molecules. Two main types of proteins exist, fibrous protein found in feathers, skin, silk and hair and globular protein found in eggs, enzymes and blood. The different structure of these molecules results in materials with different properties and functions.</p>

		<ul style="list-style-type: none"> ♦ Explain how the sequence of combining three amino acids results in the formation of different proteins. • Describe the primary and secondary structure of a simple protein ♦ Explain the importance of hydrogen bonding in the higher order structure of proteins ♦ Describe how the shape and structure of fibrous and globular proteins have different functions ♦ List three functions of proteins in supporting life. <p>Nucleic Acids</p> <ul style="list-style-type: none"> ♦ Explain the chemical groups present in the nucleic acids, DNA and RNA namely: <ul style="list-style-type: none"> ○ Five-carbon sugars, ribose and deoxyribose ○ Nitrogenous bases – adenine, guanine, cytosine, thymine and uracil ○ Phosphate group ♦ Explain how nucleotides combine in different sequences ♦ Describe the double helix structure of the DNA molecule ♦ Explain how the sequence of nitrogenous bases carries the genetic code <p>Illustrate how the sequence of nitrogenous bases allows for the synthesis of particular proteins.</p>	<p>Proteins are synthesized on the DNA molecule. This is another macro-biological molecule. The structure of this very complicated molecule can best be understood by explaining the chemical groups that make up the larger molecule.</p> <p>The sequence of the nitrogenous bases makes an infinite number of DNA molecules possible. This sequence is the genetic code and explains why there is diversity within living organisms. Unlocking this code has led to genetic engineering and cloning. With a simple understand of the structure of the molecule, learners will be able to engage in the on going public debate, in a meaningful way. This context gives opportunity to assess Learning Outcome 3.</p> <p>The link between the DNA molecule and the proteins synthesized illustrates how structure of molecules results in properties that contribute to the functioning of a biological system. Look for overlap with life sciences curriculum Maybe overload here – identify sections for examination</p>
CHEMICAL CHANGE 18,75 %			
Rate and Extent of Reaction:	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Rates of reaction and factors affecting rate (nature of reacting substances, concentration [pressure for gases], temperature and presence of a catalyst); 	<ul style="list-style-type: none"> • Explain what is meant by reaction rate • List the factors which affect the rate of chemical reactions. (Surface area (solid), concentration (solution), pressure (gas), temperature, and 		<u>Link chemical systems grade 12 – industrial processes</u>

	<p>catalyst.)</p> <ul style="list-style-type: none"> • Explain in terms of collision theory how the various factors affect the rate of chemical reactions. 		
• Measuring rates of reaction;	<ul style="list-style-type: none"> • Suggest suitable experimental techniques for measuring the rate of a given reaction including the measuring of gas volumes, turbidity (e.g. precipitate formation), change of colour and the change of the mass of the reaction vessel. 		This is an important section for illustrating and assessing understanding of investigative process, the relationship between theory and experiment, the importance of empirical data and mathematical modeling of relationships
• Mechanism of reaction and of catalysis;	<ul style="list-style-type: none"> • Define activation energy – the minimum E_k of reacting molecules that can result in a reaction. • Use a graph showing the distribution of molecular energies (number of particles against their kinetic energy) to explain why only some molecules have enough energy to react and hence how adding a catalyst and heating the reactants affects the rate. • Explain (in simple terms) how some catalysts function by reacting with the reactants in such a way that the reaction follows an alternative path of lower activation energy. 		Link to grade 11 activation energy
• Chemical equilibrium and factors affecting equilibrium;	<ul style="list-style-type: none"> • Explain what is meant by: <ul style="list-style-type: none"> ○ Open and closed systems ○ A reversible reaction ○ Dynamic equilibrium • List the factors which influence the position of an equilibrium 		Use liquid vapour equilibrium in a closed system to illustrate reversibility
• Equilibrium constant;	<ul style="list-style-type: none"> • List the factors which influence the value of the equilibrium constant • Write down an expression for the equilibrium constant having been given the equation for the reaction. • Explain the significance of high and low values of the equilibrium constant. 		

<ul style="list-style-type: none"> • Application of equilibrium principles. 	<ul style="list-style-type: none"> • Explain qualitatively, given appropriate data, the effects of changes of pressure, temperature, concentration and the use of a catalyst on the concentrations and amounts of each substance in an equilibrium mixture • Apply the rate and equilibrium principles to important industrial applications. 		
Electrochemical reactions:	Learners must be able to	Learners must be able to	
<ul style="list-style-type: none"> • Electrolytic and galvanic cells; 	<ul style="list-style-type: none"> • Define the galvanic cell in terms of <ul style="list-style-type: none"> ○ self sustaining electrode reactions ○ conversion of chemical energy to electrical energy • Define the electrolytic cell in terms of <ul style="list-style-type: none"> ○ electrode reactions that are sustained by a supply of electrical energy ○ conversion of electrical energy into chemical energy. • Define oxidation and reduction in terms of electron (e^-) transfer • Define anode and cathode in terms of oxidation and reduction. 		Link to Grade 11 matter and materials – oxidation number chemical change – redox reactions
<ul style="list-style-type: none"> • Relation of current and potential to rate and equilibrium; 	<ul style="list-style-type: none"> • Give and explain the relationship between current in an electrochemical cell and the rate of the reaction • State that the pd of the cell (V_{cell}) is related to the extent to which the spontaneous cell reaction has reached equilibrium • State and use the qualitative relationship between V_{cell} and the concentration of product ions and reactant ions for the spontaneous reaction viz. V_{cell} decreases as the concentration of product ions increase and the 		Illustrate processes microscopically

	<p>concentration of reactant ions decrease until equilibrium is reached at which the $V_{\text{cell}} = 0$ (the cell is 'flat').</p>		
<ul style="list-style-type: none"> • Understanding of the processes and redox reactions taking place in cells; 	<ul style="list-style-type: none"> • Describe <ul style="list-style-type: none"> ○ the movement ions through the solutions ○ the electron flow in the external circuit of the cell and ○ and their relation to the half reactions at the electrodes ○ the function of the salt bridge 		
<ul style="list-style-type: none"> • Standard electrode potentials; 	<ul style="list-style-type: none"> • Give the standard conditions under which standard electrode potentials are determined • Describe <ul style="list-style-type: none"> ○ the standard hydrogen electrode and ○ explain its role as the reference electrode • Explain how standard electrode potentials can be determined using the reference electrode and state the convention regarding positive and negative values. • Use the Table of Standard Reduction Potentials to deduce the emf of a standard galvanic cell • Use a positive value of the standard emf as an indication that the reaction is spontaneous under standard conditions 		
<ul style="list-style-type: none"> • Writing of equations representing oxidation and reduction half reactions and redox reactions 	<ul style="list-style-type: none"> • Predict the half-cell in which oxidation will take place when connected to another half-cell. • Predict the half-cell in which reduction will take place when connected to another half-cell. • Write equations for reactions taking place at the anode and cathode. • Deduce the overall cell reaction by combining two half-reactions 		<p>Link to oxidation numbers in Grade 11</p>

	<ul style="list-style-type: none"> • Describe, using half equations and the equation for the overall cell reaction, the following electrolytic processes <ul style="list-style-type: none"> ○ The decomposition of copper chloride ○ A simple example of electroplating (e.g. the refining of copper) • Describe, using half equations and the equation for the overall cell reaction, the layout of the particular cell using a schematic diagram and potential risks to the environment of the following electrolytic processes used industrially: <ul style="list-style-type: none"> ○ The production of chlorine (see grade 12 chemical systems: the chloral-alkali industry) ○ The recovery of aluminium metal (in South Africa) from Bauxite mined in Australia 		
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CHEMICAL SYSTEMS 18,75 %

The content and context provides opportunities to focus assessment on Learning Outcome 3, viz. evaluating

- competing knowledge claims
- the impact of science on human development
- the impact of science on the environment

It is important that teachers create the opportunities for learners to

- practice the skills they require to make such evaluations by getting them to
 - know the structure of a scientific argument and use it (“Guess-deduce-test”; Identify the proposition/hypothesis, collect evidence that supports / refutes the proposition/hypothesis, evaluate the evidence (against relevant criteria), draw conclusions (refute/accept the hypothesis) from the evidence and substantiate the conclusion using the evidence.)
 - select the relevant issues, e.g. from, say;
 - ◆ waste management,
 - ◆ use of energy (electricity),
 - ◆ use of (non-renewable) resources,
 - ◆ environmental issues ...
 - ◆ benefits to humans, positive impact on the environment say, ...
- develop the skills they require to identify (from supplied data or a text or their own knowledge) the subject content they need to substantiate their arguments, viz.

<ul style="list-style-type: none"> ○ Use a knowledge of hazardous materials to identify risk associated with particular events/processes, e.g. manufacture and transport of fuels – fire risk, CO₂, CH₄, – greenhouse gases, CFC's – negative impact on the ozone layer, Cl₂, Hg ... - toxic, oxides of nitrogen are produced by cars, CO₂ by cars and CO₂ and SO₂ and coal burning power stations during the generation of electricity – these gases are responsible for acid rain, smoke and ash (from furnaces) can cause lung diseases, and so on ○ Use criteria against which to evaluate the impact on humans, e.g. (health/ productivity – jobs / convenience/ technology (cell phones) / entertainment / safety / wealth creation ○ Use criteria against which to evaluate the impact on the environment (sustainable development), e.g. (global warming/ exploitation of non-renewable resources/ ozone layer / eutrophication / solid waste - land fills; nuclear waste, 			
<p><u>Chemical industry – resources, needs and the chemical connection:</u></p> <ul style="list-style-type: none"> • SASOL, fuels, monomers and polymers, polymerisation; 	Learners must be able to	Learners must be able to	
	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • Identify the needs South Africans have for chemicals that coal as a resource can meet • Use a simplified flow diagram of, for example, SASOL processes, to answer questions on aspects of the process. • Interpret and use data about production, consumption of raw materials, safety, to take and support a point of view • Identify economic and social benefits of SASOL • Identify environmental issues associated with SASOL production • Supplied with a text describing an operation at the plant be able to make a simple risk assessment and propose precautions that need to be taken • Describe and explain processes that SASOL uses like <ul style="list-style-type: none"> ○ Fractional distillation of air and the separation of petroleum products ○ Steam reforming of natural gas (methane) ○ Gasification of coal and its commercial and environmental significance ○ those in the SAS and slurry phase distillate reactors and their complementary nature ○ hydrocracking and the advantage for producing diesel 	<p>Link to</p> <p>Gr 11: Lithosphere – mining and mineral processing (especially coal and the fractional distillation of petroleum to produce fractions) Elimination and addition reactions</p> <p>Gr 12 rate and extent of reactions Matter and materials, plastics and polymers Chemical systems SASOL, polymerization and the manufacture of PVC Elimination and addition reactions</p>

		<ul style="list-style-type: none"> ◦ steam cracking of ethane ◦ and their role in the production at SASOL of products like <ul style="list-style-type: none"> • Ammonium nitrate (fertilizer and explosive) • Hydrocarbons (fuels - also give relevant combustion reaction equations) • Ethene (elimination) • Polypropylene <p>Describe issues concerned with the recycling of polymers</p>	
<ul style="list-style-type: none"> • The chloroalkali industry (soap, PVC, etc); 	<ul style="list-style-type: none"> • Given diagrams of any one of the three types of cell used industrially to produce chlorine electrolytically: <ul style="list-style-type: none"> ◦ explain the process using half reactions and the overall redox reaction taking place in the cells ◦ identify all the products and give a use of each ◦ make clear the meaning of the term electrolytic cell ◦ identify the cathode (reduction, H_2) and anode (oxidation, Cl_2) ◦ describe the function of the cell membrane where applicable (ion exchange) • Identify the benefits to humankind of the products of this process • Identify risks associated with operating each of these cells • *Compare the three cell types provided with a table of data, for example <ul style="list-style-type: none"> ◦ Cell voltage (V) ◦ NaOH strength (wt%) ◦ Steam consumption (kWh/MT Cl_2) for concentration to 50% NaOH as to which cell is more efficient. • Given a flow diagram of, for example, the membrane cell (or 		

	<p>even an unknown process pertinent to the manufacture of these products), be able to answer questions on aspects of the process. For example identify the reactants and products of a particular step, or the purpose of a sequence of steps.</p> <ul style="list-style-type: none"> • Give an equation for the production of soap from animal fat and NaOH and describe how the structure of the soap molecule relates to its function • Describe how the structure of a detergent is different to that of soap and the consequent advantage of detergents over soaps • Evaluate the impact of the use of detergents on humankind and the environment. 		
<ul style="list-style-type: none"> • the fertiliser industry (N, P, K). 	<ul style="list-style-type: none"> • List, for plants, <ul style="list-style-type: none"> ○ three essential nutrients and their source; C, H and O (atmosphere (CO₂) and rain) ○ three primary nutrients and their source N, P and K (the soil) • Explain the function of N, P and K in plants • List for humans the four major elements, and their source, on which the body relies for form and function; C, H, O and N (atmosphere, water and food – animals and plants) • Match the parts of the human body that utilize particular chemical elements with those from a list of primary, secondary and micronutrients in plants (e.g. P, K, Fe, Ca, ...) • Give the form in which plants and animals absorb N, P and K (e.g. nitrates, phosphates, potassium 		<p>Link to</p> <p>Gr 10: Chemical Systems - the nitrogen cycle</p> <p>Gr 11: Lithosphere – mining and mineral processing (especially phosphates and potassium salts) Acid and base reactions – especially neutralisation</p> <p>Gr 12 rate and extent of reactions Chemical systems SASOL the manufacture of fertilizers</p>

	<p>salts, ... implies the need to fix nitration)</p> <ul style="list-style-type: none"> • Give the source of N (guano), P (bone meal) and K (German mines) before and after the first world war • Interpret the N:P:K fertilizer ratio • Describe and explain (rates, yields, neutralization, ...), using chemical equations where ever appropriate, these aspects of the industrial manufacture of fertilizers, given diagrams, flow charts and so on <ul style="list-style-type: none"> ○ N₂ – fractional distillation of air ○ H₂ – at SASOL from coal and steam ○ NH₃ – Haber process; ○ HNO₃ – the Ostwald process; ○ H₂SO₄ – including the contact process; ○ H₃PO₄; Ca (H₂PO₄)₂ (super phosphates) ○ NH₄NO₃; (NH₄)₂SO₄; H₂NCONH₂ (urea); • Give sources of potash (mined imported potassium salts like KNO₃, K₂SO₄, KNO₃,) • Describe the term eutrophication and <ul style="list-style-type: none"> ○ what causes it ○ its consequences ○ be able to identify circumstances that can lead to it from a supplied text ○ suggest ways to prevent it ○ suggest ways to solve the problems that arise from it • Evaluate the use of inorganic fertilizers on humans and the environment . 		
<ul style="list-style-type: none"> • Batteries, torch, car, etc. 	<ul style="list-style-type: none"> • Use the knowledge gained studying galvanic cells to provide, for an unknown cell 		<ul style="list-style-type: none"> • One of the main benefits of recycling batteries lie in the energy savings of recapturing a

the equation for the cell reaction
given the half equations
the cell voltage if supplied with
the voltage of the half cells

- Explain and use the concepts:
energy stored in cells and batteries
 $W = Vq$
cell capacity and use the unit
Amp-hour (Ah and mAh) and
the equation $q = It$
primary cells and secondary cells
- Describe features of cell structure
and explain qualitatively the
relationship between
cell emf and the electrochemical
reaction (e.g. lithium-ion is 3,6
V while NiCad is 1,2 V)
internal resistance and the
distance between electrodes
cell current and the surface area of
the electrodes
cell capacity and amount of
electrolyte
- Give a labeled schematic diagram
of a lead-acid accumulator showing
its structure and components. Use
the lead acid accumulator to
Explain the relationship between
the structure of the battery and
its internal resistance, maximum
current, capacity and emf
Explain the relationship between
battery emf and the connection of
cells
 - Show the relationship between
the half reactions and overall
reactions during the discharge
and recharge cycles
 - Determine the emf using the
voltages for the half reactions
 - Explain the functioning of a
secondary cell including the
relationship between the emf and

product compared with mining a
virgin resource.

- Link to electrochemistry
- Maybe overload here – identify
sections for examination

- the voltage at which it needs to be charged
- Discuss issues around disposal / recycling of battery components
 - Give a labeled schematic diagram of a zinc-carbon dry cell (Leclanché) showing its construction and components
 - Give the half reactions and overall reactions during discharge
 - Determine the emf from the voltages of the half reactions
 - Explain the functioning of the cell
 - Explain the relationship between the structure of the battery and its internal resistance, maximum current, capacity and emf
 - Given a diagram of an unknown primary or secondary cell, the half equations and half cell voltages be able to comment on issues relating structure and reaction equations to discharge and recharge cycles (secondary cells), cell emf, capacity, internal resistance and maximum current,
 - Evaluate the impact of the use of batteries on humans and the environment

Date:

To:

Email Address :

For Attention:

Subject: **REQUEST FOR ASSISTANCE WITH MASTER'S STUDY ON TEXTBOOK READABILITY**

Dear

I am registered as a part time student at Rhodes University (student number 09V6644). I have been studying for a Master's degree in Science Education since February 2009 and am researching the readability of selected Physical Science Grade 10 textbooks.

Prior research studies indicate that educator intuition strongly supports quantitative and qualitative textual research findings on readability. The publishers and editors of the science textbooks are also urgently needing feedback on the current texts before they go into their second reprints.

I would appreciate permission to contact the physical science educators (Grade 10) to set up a focus group discussion where they share their impressions of the readability and usefulness of the textbook/s they are using. The group discussion need not take more than an hour and I would be glad to accommodate the educators at their convenience.

The school and teachers are assured of anonymity in the final research report and will be invited to proofread drafts of the report to ensure that details are accurately recorded and reported.

Should you have any concerns or questions about this request, I can be contacted on (023) 5411881 or 0834566090.

I would be most grateful if you would give my request your consideration.

Yours sincerely

Lesley van Heerden

APPENDIX B

Section 1: Matter and Materials

	Sample 1	Sample 2	Sample 3	Fry's	Sample 4	Sample 5	Sample 6	Fry's	Sample 7	Sample 8	Sample 9	Fry's
No. of Sentences	6.9	6.9	9.7	7.833333	7.1	6.9	8.4	7.466667	7.3	8.6	8.8	8.233333
Average Sentence Length	14.49275	14.49275	10.30928		14.08451	14.49275	11.90476		13.69863	11.62791	11.36364	
No. of Syllables	167	146	183	165.3333	166	147	138	150.3333	161	195	173	176.3333
% Difficult Words	24	17	33		32	11	10		32	43	33	
Average Word Length	1.67	1.46	1.83		1.66	1.47	1.38		1.61	1.95	1.73	
Dale-Chall - original	8.144941	7.039641	9.35854	11	9.387892	6.092241	5.805976	8	9.368752	11.00294	9.410836	15
New Dale-Chall (Tables)	10	8	12		12	6	4		12	16	12	
FKRA Formula	9.768174	7.290174	10.02462		9.490958	7.408174	5.336857		8.750466	11.95488	9.255818	
New Dale Chall (Tables)	10											
Fry's Readability	11											
FKRA Formula	9											

Section 2: Chemical Change

	Sample 1	Sample 2	Sample 3	Fry's	Sample 4	Sample 5	Sample 6	Fry's	Sample 7	Sample 8	Sample 9	Fry's
No. of Sentences	6.5	8.7	8.3	7.833333	6.4	5.7	8	6.7	6.3	5.9	6.9	6.366667
Average Sentence Length	15.38462	11.49425	12.04819		15.625	17.54386	12.5		15.87302	16.94915	14.49275	
No. of Syllables	173	207	175	185	160	167	145	157.3333	181	202	178	187
% Difficult Words	27	43	23		38	33	29		37	33	35	
Average Word Length	1.73	2.07	1.75		1.6	1.67	1.45		1.81	2.02	1.78	
Dale-Chall - original	8.662877	10.99631	7.86579	15	10.4117	9.717375	8.8356	10	10.2661	9.687878	9.881841	15
New Dale-Chall Reading (Tables)	12	16	8		15	14	10		15	15	15	
FKRA Formula	10.824	13.31876	9.758795		9.38375	10.95811	6.395		11.95848	14.85617	11.06617	
New Dale-Chall (Tables)	13											
Fry's Readability	13											
FKRA Formula	11											

Section 3: Chemical Systems

	Sample 1	Sample 2	Sample 3	Fry's	Sample 4	Sample 5	Sample 6	Fry's	Sample 7	Sample 8	Sample 9	Fry's
	5.2	8.1	3.8	5.7	5.9	7.7	7.2	6.933333	5.1	7	7.6	6.566667
No. of Sentences	19.23077	12.34568	26.31579		16.94915	12.98701	13.88889		19.60784	14.28571	13.15789	
Average Sentence Length	140	134	158	144	175	164	162	167	159	175	161	165
No. of Syllables	18	10	27		31	32	21		26	35	35	
Average Word Length	7.432546	5.827846	9.205063	8	9.372078	9.333456	7.641289	11	8.714449	9.871571	9.815632	11
Dale-Chall	8	4	14		14	12	8		12	14	14	
Flesch Reading Ease	67.21231	79.87223	44.18016		40.11551	53.78581	54.48439		50.72296	43.04929	56.13558	
FKRA Formula	8.43	5.036815	13.31716		11.67017	8.826935	8.942667		10.81906	10.63143	8.539579	
Fry's Readability	10											
Flesch Reading Ease	54.39536											
Flesch Reading Grade	12.85355											
FKRA Formula	9.579312											
Dale-Chall	11.55556											
Fry's Readability Graph	10											
Flesch Reading Grade	13.531											
FKRA Formula	10											

Section 1: Matter and Materials

	Sample 1	Sample 2	Sample 3	Fry's Sum	Sample 4	Sample 5	Sample 6	Fry's Sum	Sample 7	Sample 8	Sample 9	Fry's Sum
No. of Sentences	6.4	8.5	7.3	7.4	3.9	4.8	6.5	5.066667	6	6.2	6	6.066667
Average Sentence Length	15.625	11.76471	13.69863		25.64103	20.83333	15.38462		16.66667	16.12903	16.66667	
No. of Syllables	178	146	160	161.3333	147	164	163	158	164	159	170	164.3333
% Diffiecult Words	25	19	29		19	26	26		35	26	31	
Average Word Length	1.78	1.46	1.6		1.47	1.64	1.63		1.64	1.59	1.7	
Dale-Chall - original	8.359	7.220129	8.895052	10	7.908395	8.775233	8.504977	11	9.989667	8.5419	9.358067	12
New Dale-Chall (Tables)	10	8	12		11	12	10		15	10	12	
FKRA Formula	11.50775	6.226235	8.632466		11.756	11.887	9.644		10.262	9.462323	10.97	
Dale-Chall	11											
Fry's Readability	11											
FKRA Formula	10											

Section 2: Chemical Change

	Sample 1	Sample 2	Sample 3	Fry's Sum	Sample 4	Sample 5	Sample 6	Fry's Sum	Sample 7	Sample 8	Sample 9	Fry's Sum
No. of Sentences	8.6	5.6	4.8	6.333333	5	5.6	6.2	5.6	6.7	5.2	7.2	6.366667
Average Sentence Length	11.62791	17.85714	20.83333		20	17.85714	16.12903		14.92537	19.23077	13.88889	
No. of Syllables	171	157	150	159.3333	170	166	168	168	168	170	164	167.3333
% Diffiecult Words	20	21	26		24	23	28		31	23	23	
Average Word Length	1.71	1.57	1.5		1.7	1.66	1.68		1.68	1.7	1.64	
Dale-Chall - original	7.371244	7.838114	8.775233	10	8.4181	8.153914	8.8577	13	9.271699	8.222046	7.957089	12
New Dale-Chall (Tables)	8	10	12		10	10	12		12	10	10	
Flesch Reading Ease	49.36086	54.34336	56.98708		40.985	46.72936	46.94087		48.2667	41.83231	52.79239	
FKRA Formula	9.122884	9.900286	10.235		12.27	10.96229	10.52432		10.0549	11.97	9.178667	
Dale-Chall	10											
Fry's Readability	12											
FKRA Formula	10											

Section 3: Chemical Systems

	Sample 1	Sample 2	Sample 3	Fry's Sum	Sample 4	Sample 5	Sample 6	Fry's Sum	Sample 7	Sample 8	Sample 9	Fry's Sum
No. of Sentences	6	4.5	5.5	5.333333	6	5.5	4.1	5.2	6	5.5	6	5.833333
Average Sentence Length	16.66667	22.22222	18.18182		16.66667	18.18182	24.39024		16.66667	18.18182	16.66667	
No. of Syllables	154	156	157	155.6667	147	153	140	146.6667	182	140	131	151
Dale-Chall - original	8.252767	7.423022	7.538418	10	6.989567	11.80172	7.530556	9	8.726467	6.117318	6.200067	9
New Dale-Chall (Tables)	10	10	10		8	16	9		11	6	6	
Flesch Reading Ease	58.19267	50.38122	53.98573		64.11467	57.36973	61.52915		34.50467	68.36773	77.65067	
FKRA Formula	9.082	11.48467	10.02691		8.256	9.554909	10.4422		12.386	8.020909	6.368	
Dale-Chall	10											
Flesch Reading Ease	58.45514											
Flesch Reading Grade	12.24397											
FKRA Formula	10											

Study & Master

Readability Data : Dale-Chall Formula / Fry's Readability / Flesch Reading Ease

Section 1: Matter and Materials

	Sample 1	Sample 2	Sample 3	Fry's			Sample 4	Sample 5	Sample 6	Fry's Sum	Sample 7	Sample 8	Sample 9	Fry's Sum
No. of Sentences	7.6	7.9	9.2	8.233333			5.8	5	5.3	5.366667	8.4	6	7.7	7.366667
Average Sentence Length	13.15789	12.65823	10.86957				17.24138	20	18.86792		11.90476	16.66667	12.98701	
No. of Syllables	171	150	171	164			156	159	131	148.6667	162	187	154	167.6667
% Diffiecut Words	35	29	33				25	24	13		35	34	27	
Average Word Length	1.71	1.5	1.71				1.56	1.59	1.31		1.62	1.87	1.54	
Dale-Chall -original	9.815632	8.843448	9.38633	10			8.439172	8.4181	6.625049	9	9.753476	9.831767	8.543956	11
New Dale - Chall (Tables)	13	11	12				11	10	8		12	15	10	
Flesch Reading Ease	47.67558	65.99196	50.19617				55.86762	50.291	75.22598		56.6699	30.27467	62.24581	
FKRA Formula	9.719579	7.046709	8.82713				9.542138	10.972	7.226491		8.168857	12.976	7.646935	
Dale-Chall (Tables)	11													
Fry's Readability	10													
FKRA Formula	9													

Section 2: Chemical Change														
	Sample 1	Sample 2	Sample 3	Fry's Sum			Sample 4	Sample 5	Sample 6	Fry's Sum	Sample 7	Sample 8	Sample 9	Fry's Sum
No. of Sentences	5.1	5.2	5	5.1			5.4	6.4	6.4	6.066667	7.3	6.7	7	7
Average Sentence Length	19.60784	19.23077	20				18.51852	15.625	15.625		13.69863	14.92537	14.28571	
No. of Syllables	184	159	161	168			147	184	188	173	169	169	156	164.6667
% Diffiecut Words	27	31	32				17	35	37		32	26	30	
Average Word Length	1.84	1.59	1.61				1.47	1.84	1.88		1.69	1.69	1.56	
Dale-Chall - original	8.872349	9.485246	9.6813	13			7.239319	9.938	10.2538	15	9.368752	8.482199	9.082071	11
New Dale-Chall (Tables)	12	13	14				8	15	15		12	10	12	
Flesch Reading Ease	29.57296	51.13831	48.599				62.07485	33.96006	30.57606		48.77196	47.4207	59.12329	
FKRA Formula	13.76906	10.672	11.208				8.978222	12.21575	12.68775		9.694466	10.1729	8.389429	
Dale-Chall (Tables)	12													
Fry's Readability	13													
FKRA Formula	11													

Section 3: Chemical Systems														
	Sample 1	Sample 2	Sample 3	Fry's Sum			Sample 4	Sample 5	Sample 6	Fry's Sum	Sample 7	Sample 8	Sample 9	Fry's Sum
No. of Sentences	8.5	5.8	7.3	7.2			5.8	6.3	6.4	6.166667	9.1	7.8	6	7.633333
Average Sentence Length	11.76471	17.24138	13.69863				17.24138	15.87302	15.625		10.98901	12.82051	16.66667	
No. of Syllables	152	150	148	150			177	136	158	157	163	182	181	175.3333
Average Word Length	1.52	1.5	1.48				1.77	1.36	1.58		1.63	1.82	1.81	
New Dale-Chall (Tables)	8	8	8				10	10	10		10	11	12	
Flesch Reading Ease	65.28418	60.94362	66.53796				38.10162	74.29487	55.95606		56.8326	38.74121	35.35067	
FKRA Formula	6.934235	8.834138	7.216466				12.02014	6.648476	9.14775		7.929714	10.886	12.268	
Dale-Chall - (Tables)	10													
Fry's Readability	11													
Flesch Reading Grade	12.8121													
FKRA Formula	9													

ASSESSMENT OF THE COMPREHENSION OF NON-TECHNICAL WORDS

The instructions are quite simple!

- For each question, **choose ONE answer** that you feel best explains the word in bold.
- **Order your choice** of an answer.
- You may use pen or pencil.
- You don't have to put your name on the sheet.

And....MANY THANKS FOR GIVING THE QUESTIONS YOUR BEST ATTENTION!

1. The speed **limit** was 40 kmph. This means that cars had to travel

- A at not more than 40 kmph.
- B at exactly 40 kmph.
- C between 35 and 45 kmph.
- D at an average of 40kmph

2. The rainfall was **average** for May. This means that it was

- A the highest ever for May.
- B about normal for May.
- C the lowest ever for May.
- D higher than any other month.

3. Which sentence uses the word **accumulate** correctly?

- A The cars accumulate as they go down the hill.
- B The crowd accumulate the goal scorers.
- C The classroom would accumulate 30 students.
- D The falling leaves accumulate in corners of the garden in Autumn.

4. Which one of the following sentences uses the word **effect** correctly?

- A The teacher could not effect the work of the students .
- B The effect of heating water is that it boils.
- C It took considerable effect to move the boulder.
- D He thought that his smiling would effect everyone.

5. The crowd was able to **disperse** after the football match was over. This means that the crowd

- A chanted and sang.
- B caused no trouble.
- C went away in all directions.
- D stayed in the ground.

6. Which of the following sentences uses the word **contrast** correctly?

- A The painter used black beside white as a contrast.
- B The contrast lines on the map show where the hills are.
- C Many short stories were contrasted to make the book.

D As the metal cooled rapidly, it was seen to contrast.

7. Which sentence uses the word **composition** correctly?

- A There was no composition on the price for senior citizens.
- B The composition of the bricks depends on the materials used to make them.
- C School is not composition when you are seventeen years old.
- D The guard dog roamed the composition round the factory.

8. The explorers knew the **source** of the river . This means that they knew

- A its length.
- B where it went to.
- C its breadth.
- D where it began.

9. Which sentence uses the word **simultaneous** correctly?

- A Stick insects try to simultaneous twigs to avoid being seen.
- B The teams' appearances were so simultaneous that it was difficult to tell them apart
- C The two explosions were simultaneous and sounded like one.
- D After the teacher's simultaneous of the problem, the student understood how to solve it.

10. Which sentence uses the word **consistent** correctly?

- A Hydrogen was a consistent of the mixture.
- B The Member of Parliament met a consistent in London.
- C The opinions of the three doctors about the patient, were consistent.
- D She came a very close second in the competition and received the consistent prize.

11. The girls sat in **adjacent** seats. This means that the seats were

- A next to each other.
- B opposite each other.
- C as far apart as possible.
- D identical in every way.

12. This chapter will **illustrate** the point made in the last chapter. This means that it will

- A gloss over the point.
- B contain more paragraphs.
- C leave out the point.
- D make the point clearer.

13. The hospital had to **isolate** the man with the infectious disease. This means that the hospital

- A gave him an injection.
- B operated on him immediately.
- C had to find out the cause.
- D put him completely by himself.

14. **Classify** the collection of sea shells. This means

- A clean them
- B count them
- C put them in similar groups
- D paint them with varnish

15. Which sentence uses the word **omit** correctly?

- A He was not prepared to omit that he had been wrong.
- B The seaman saw the arrival of the bird as a good omit
- C As the time was short, she decided to omit the last piece of homework.
- D It was possible to omit the student to the class because of the circumstances.

16. The exam was a **percentage**. This means that it was

- A given to all students.
- B a large number.
- C the average of the class.
- D out of one hundred.

17. The apples were **abundant** last year. This means that

- A they were larger than normal.
- B there was a shortage of them.
- C they were ready for picking earlier.
- D there were plenty of them.

18. When cauliflower is boiled for too long it **disintegrates**. This means that it

- A disappears.
- B changes colour.
- C breaks up into smaller pieces
- D dries out rapidly.

19. Which sentence uses the word **essential** correctly?

- A The dress designer decided that it was more essential to use the electric scissors.
- B He used essential jam in his sandwich, which ran out as he bit it.
- C The painter thought he had essential paint to finish the job.
- D It is essential to wear a seat belt when driving a car.

20. Which sentence uses the word **estimate** correctly?

- A Khalid used his dictionary to estimate the answer.
- B A clock can estimate the time.
- C Many plants grow well in the warm sheltered corner of the estimate.
- D For rolls of wall paper was her estimate to cover the walls of the room.

21. Which sentence uses the word **proportion** correctly?

- A He chose another proportion of the delicious pie.
- B In the drawing, the figures and buildings were in proportion.
- C He made a proportion of marriage to the girl.
- D The chairperson made a proportion to the shareholders.

22. Which sentence uses the word **efficient** correctly?

- A Children need to eat efficient food to grow strong and healthy
- B The man did not eat fresh fruit and vegetables and, as a result , he was efficient in vitamins.
- C Large brooms are more efficient than small ones for sweeping the yard.
- D The man did not have efficient qualifications for the job.

23. Which sentence uses the word **reference** correctly?

- A The man in charge of the match was a good reference.
- B At the ceremony, the rituals were performed with much reference.
- C The reference of the materials was just enough to make a dress.
- D During our hill walk we made reference to the map.

24. Which sentence uses the word **maximum** correctly?

- A The lazy student used the maximum effort in his work.
- B The team won the maximum number of points and so were relegated.
- C When she sold her car she wanted to make the maximum profit.
- D By dividing the total number of points by the number of students who sat the test, the examiner was able to work out the maximum score.

25. The student enjoyed the **initial** part of the lesson most of all. This means that she enjoyed

- A the last part.
- B the crucial part
- C the first part

D the group work

APPENDIX C

SCHOOL A

Focus Group Discussion

Readability of the Chemistry Textbooks used at Grade 10 Level

Background

School A is a former model C secondary school where science is taught in the home language of the pupils. The school has approximately 650 learners and the grade 10 science class has 30 learners. Mr Van Der Walt * and Miss Le Grange* form the science department. Mr Van Der Walt has taught science for 35 years and Miss Le Grange is newly qualified with a B.Sc. / HOD from the University of Stellenbosch. She has taught for 2 years.

They have the Study and Master Physical Science Textbook for grade 10 but have discarded it in favour of a physical science workbook: Cruising Science.

Response to discussions around the following questions:

1. **Using the textbook in the class...what “works for you” in the particular textbook and what do you find a problem or a hindrance?**

Discussion: The textbooks have a way of “jumping in” with a **concept** without clarifying or explaining them. They tend to simply use the concept as though the pupil would understand what they are talking about. They “start”... launch into a topic or concept without giving it background or proper attention. An example of this is “magnetic flux”. This is an extremely difficult and unfamiliar concept for learners yet the textbook just uses the term, assuming the learner is familiar with it. The writer doesn’t take the trouble to first bring it to the level of the learner and then build from there.

The **vocabulary** used is a problem. We have to use correct vocabulary and scientific vocabulary but too much of it is not properly explained or supported. The books are even a problem for the English speaking learners

The **layout of the textbook** is not user friendly with sufficient examples. The books have some worked examples but insufficient examples for the pupils to do and practice. The problems are often inappropriate and of an incorrect standard. The book which we find works better for us is the workbook: Cruising Science. Here, in this book, the concepts are clearly explained and summarised and then there are step-by-step problems for the pupils. The problems take the pupils through each concept in a progressive way making them do problems which reinforce the concept.

The **graphicacy** in our former textbook or the textbook recommended by the Department isn’t clear. Some of the diagrams are far too complex and put the pupil off before they’ve even started. Mind maps, diagrams and pictures need to be relevant and they often aren’t. They are not supported by the text. They are pictures filling places and making the book “look nice”. This helps with the marketing maybe but not in the classroom. It proves to be a hindrance.

The **print** needs to be clear and S&M has an uncomfortable font and long paragraphs. Chunks of writing that tire the readers. Big bold print is user friendly and we find that this is what Cruising Science has done.

When it comes to **content**, the books are also too full of useless stuff, excess baggage that publishers and authors have used to pad the book and make it look good. This gets in the way when trying to teach from the book or use it as a support. Pupils can't distinguish between what is important and what is irrelevant. We have to do that as teachers: experience the textbooks and then guide the pupils. When the textbook is so full of excess "rubbish", this "pre-experiencing" that needs to take place simply takes up too much time and so the book is discarded.

Some **content** is "nice to have" but we don't have time for it and it clutters the text and distracts the pupils. We teach towards an exam and we need a textbook that caters for this purpose. Enrichment is something that we can source on our own and give it to the pupils; their textbook must be functional.

It would be good to be able to follow a textbook from the beginning knowing that it is preparing the learner thoroughly for the next grade. But we can't do this. If we follow the textbook, we won't have prepared learners. Sticking to the grade 10 textbook does lay sufficient groundwork for grade 11 eg: mol concept.

There is insufficient time given to the development of the current textbooks. They are obviously being written with deadlines. Some were written before the curriculum was published and so are misleading in their depth and their content. This problem makes it impossible for us as teachers to "trust" as textbook.

2. Background knowledge affects readability. With respect to the pupils arriving in grade 10, how prepared are they for physical science? What is the foundation like?

Discussion around the question: The problem in grade 10 is carried over from grade 8 and 9. There insufficient time is given to physical science. Life sciences are given more attention as teachers are more comfortable with Life Sciences but the Physical Sciences are often poorly taught. Certain concepts aren't taught or are incorrectly taught and this makes it difficult to teach the grade 10 curriculum. The books assume a background knowledge that the pupils do not have. It would help to have a summary at the beginning of a chapter just wrapping up the background knowledge necessary to continue with the concepts. We could then revise those first and then continue.

SCHOOL B

Focus Group Discussion

Readability of the Chemistry Textbooks used at Grade 10 Level

Background

School B is a secondary school located in the township where science is taught in English to home language Xhosa pupils. The school has approximately 1200 learners and the grade 10 science class has 45 learners. Mrs Mkela [T1] * and Miss Sidi [T2]* form the science department. Mrs Mkela has taught Physical Science for 25 years and Miss Sidi has taught Life Sciences for 20 years. They have the Study and Master Physical Science Textbook for grade 10 and the Oxford Successful Science Series for grade 10.

Response to discussions around the following questions:

M: I wanted to say something about prior knowledge...readability of a textbook and prior knowledge are related. What about the grade 10 learners prior knowledge?

T1: Ja, because they come up with the idea that you must have a context. When you are going to start with the lesson first you must have a context, you must understand where you are going to apply whatever. You know you have to start there...and what about the time...(teacher's way of explaining how she ascertains prior knowledge and even understand what is prior knowledge)

T1: The concepts...you just want to get to the **concepts**. That is what I am saying...I wish the book could have the prior knowledge. It must first get to the prior knowledge. (I say to the pupils) Tomorrow I am going to start with something, go today and study the prior knowledge...so that they can remind them of what they have done last year. Then when you come into the class and start with the lesson you can just remind them about questions...what is this? How about this? Wake that prior knowledge up..

For instance electricity...you know what you want to do in grade 10 and you can just get them to remind themselves about grade 9 stuff.

It would help if the textbooks had the prior knowledge...

[Layout...]

T2: and it must be simple. Not paragraphs and paragraphs...like Study& Master. Bullet forms. Points. Study & Master is too complex. The paragraphs, solid like that make the learners afraid.

(discussion about prior knowledge in the Prac Maths series of books where summaries are first given of grade 9 work)

T1: it is there (with the prior knowledge questions) that you can find out what these learners haven't done. You know we have got learners, a lot of them that come from other schools, feeder schools. Because they are coming from rural areas...and there is no prior knowledge. They don't speak

English well and understand and they will say: “sorry miss, in this school you are speaking too much English ... (laughs)...and I think the environment too...

T1: in these rural places, there are too much gaps there is a lot that they leave out. And these learners come to our school and it is a lot of work. And we accept a learner that is coming from grade 9 in another place and they have done only a little bit. Like a little bit of electricity, they know very, very little. They will not know what you are talking about, they have never even done and you know it is not easy to take that learner over because there is a lot they don't know...

(Discussion on my own teaching of Louisa (a Sotho learner)...discussion of words...phases....matter...difficulties and no background knowledge...)

T2: And abstract **concepts**...matter, air...

(distracted as we discussed her problems with the new and old system...in the old system she got 100% pass rate from her learners...this has changed...why? for 5 years...but since 2008, the graph is going down. And I am always asking myself why...)

T2: the new system is not bad. It is a good system but it is too much. The content is too much, too quickly.

(discussion of Cruising Science....simple and full of problems for the learners to work through)

T1: we cannot just run and change. Make progress too quickly. We want to get like other countries but there is the transition. We are struggling

Start....

(taping all the beginning...)

M: The feedback and your thoughts that the problem is in grade 9...

T1: yes. When they come from grade 9 a lot of things are not done. Background knowledge is lacking. Another thing is how to **comprehend science concepts**...the conceptual knowledge is poor. The concepts of science are difficult, they are abstract. This is the problem for many teachers. You have to unpack them and the if the teacher has been a little bit confused unpacking then the learner will bring to grade 10 many problems...

T1: the problem is the teaching in grade 9 and often the teachers are not trained even in the natural sciences. You just take a teacher from life sciences and you say: can you teach the natural sciences. And so they give more attention to the life sciences and matter and materials gets left. Earth and beyond also gets attention but matter and materials again gets left.

T1: yes...the grade 9 teachers they focus on what they know which is more the life sciences...actually we need to get more teachers who are competent to do natural sciences and teach them how to focus on the physical sciences part of the curriculum too. That's why we are having that problem with the physical sciences and that is why we are struggling.

M: life science....not so conceptual...lots of learning... but not so many concepts..

T1: as long as a learner knows how to read and study the life sciences are fine. You don't have to understand so deeply. You just have to know what is the function of this part or that one...

T1: You see, grade 10 is a main hurdle. If a learner manages to understand grade 10 that learner will be alright to grade 12. The moment a learner battles with grade 10...it is bad.

T1: S&M...talking to some of my learners...The other one said that in Cape Town they are using Oxford: the learner said it is a nonsense book. Not enough explanations and they go to questions. I asked about S&M: difficult concepts and difficult language for a second language learners. My learners are second language and that book is too difficult.

M: can they read the textbook unaided?

T2: oh...the comprehending. I let them read in the classroom so that they can find out about their book. Then they will read a little bit and then I say: let's discuss what you have just read...then it is a problem. Because they can read all of the vocabulary but now to understand what they are reading. It is so difficult for us to accelerate our teaching because progress...to make them understand ...and you find out that there is a lot of content that is so difficult in the new system which is a little bit difficult in second language schools. In the classroom you have to explain...you can't just say this is homework, go home and read it and come back and we'll move on. So you are often leaving a lot of learners behind.

M: class sizes?

T1: 45...

T1: there is another textbook that is I have been looking at Olivier...a good book. Quite expensive but I have bought it and to me I think that it is explaining well. The explanations are accommodating the language. Usually I print it and I give it to my learners so that it can help when they do not understand when they are doing their learning.

M: discuss Cruising Science...

T1: Focus is a problem. They said to me (the learners) that S&M is not so difficult to 1st language learners.

(discussion about textbooks and financing....)

T1: you can't start in grade 10 with difficult terms and language. We need straight forward. That is our problem ...learners are running away from physical science because the language is so difficult...

(discussing in general our stats...)

T1: Literacy is a problem. We are teaching learners with a lot of backlog. We are doomed. Because whatever we are trying to do, we are trying the impossible because we have learners that are already having problems. If a learner missed some concepts it is very difficult when that learner is in high school to catch up.

T1: we need to concentrate more on the intermediate phase. 7-9

T1: I have a daughter at a model C school in grade 1. She is learning much quicker. So she will have an advantage with English. Here at my school, we are struggling to get the parents involved.

M: Olivier...

T1: using Olivier a lot...

T1: the textbook we have now is a little bit of a problem so that as the teacher you need to do more. You can't rely on your textbook.

M: and your learners...they need the textbook?

T1: yes, they need the text book! We can't do notes in the class. We have to use our textbook. When they have a new section...yes the textbook is a big help. There are teachers that are behind because they do not have enough textbooks. We need our textbooks to make progress. The textbook helps us to keep up with the work schedule.

(moving tables....)

T1: if they are writing...the textbooks...they can put in brackets sometimes, some of the meanings. Even a glossary having Xhosa or Zulu terms. When I ask my grade 12 learners what is difficult when you come to answer the questions and the learners tell me that it is the way the questions are asked, the language. They often say that there is one word that they do not understand and this gives them too many problems. A glossary...helping to accommodate 2nd language learners.

[M: thanking them for their time and all that they'd shared and outlining the procedure further]

SCHOOL C

Focus Group Discussion

Readability of the Chemistry Textbooks used at Grade 10 Level

Background

School C is a secondary school situated in the township where science is taught in English to pupils whose home language is Xhosa. The school has approximately 950 learners and the grade 10 science class has 30 learners. Mr Mofokeng [T3] *, Miss Bekha [T1]* and Miss Letaba [T2]* form the science department. Mr Mofokeng has taught science for 35 years, Miss Bekha and Miss Letaba have taught for 10 and 12 years respectively. They have the Study and Master Physical Science textbook for grade 10 as well as the Focus Science grade 10 textbook.

Response to discussions around the following questions:

M: What grades are you teaching? And textbooks? Which are you using and how do you find them?

T1: Grade 10 to 12 and I am using Study and Master and Oxford

Oxford is for is to me is not helpful is too difficult when questioning of physical science, Study and Master is too vague for most learners, those are gifted, those that bright, is it okay. And the questioning...it is totally different to the questioning of the exam papers. I prefer not to use those questions...they are very easy, very simple. When it comes to the question paper it is another way of questioning...to train the learners of how to answer and how the questions are questioned in the question paper.

Study and Master is good but is not so good for those learners that are not so bright, [the strugglers] it is too difficult for them because it is a lot of notes, there is not a lot of simplification...and understanding for each and every concept sometimes. Also no glossary at the back...that is a difficult part but Oxford has a glossary but not all the concepts are in the glossary and it doesn't simplify enough and try to make a summary so I must collect different textbooks so that I can teach in class when it comes to teaching with a text book I find that this textbook is better in that section than this one so I must use this one for that section the one that is bought by the school can't just be used

The Kagiso Sen. Sec. for grade 12 physical science, it doesn't simplify enough the textbooks all have there hiccups and when it comes to questioning the questions are too easy

M: [interrupted] Vocabulary....they are able to read them on their own? Can you instruct them to go home and are they able to read comprehensively and make notes?

T1: okay like I for one, I make them make notes but I don't take those notes as the final one, I combine the notes with them and help them and look at the notes...our learners they are taught physical science in English but since we are the Xhosa speaking teachers it is not easy for us as teachers to teach the whole period in English. We have to go back to Xhosa so as to make sense of the material so I use code switching all the time to the extent that on the notes I give them opportunity to write in the Xhosa. I think that I am spoon feeding them in that I help but the

language barrier is a problem and in understanding and analyzing what is written is also difficult and that is why the glossary is so important

There are concepts like equilibrium...you can get equilibrium in English, you can get equilibrium in Geography, even in Physics, even in Life Sciences but the way it is written is the same but it has a different meaning in each and every subject. So...those concepts and there are many concepts which are too difficult for our learners, even for the understanding. Let's say this ball has its own velocity, velocity is the speed... and also...how can they differentiate all those stuff, those concepts...(velocity and speed are different) to take it to other learning areas...to make one it is too difficult. That is why they say that physical science is too difficult because they say no to the textbook the textbook is too difficult

M and T1 and T2: (general discussion on everyday meaning and scientific meaning of words and the confusion. Speaking of 'power' and how power has the meaning: ie powerful soap...yet in physics: rate at which work is done yes...yes...agreeing... consent....)

T2: science is difficult in their perspective because what it's one meaning has two meanings. Like weight...is your mass but when we come to physical science weight is not our mass any more. We have to switch now and explain that it is not what everybody agrees with. We've got the challenge of first getting the learners geared to the concept before we can take the concept and support it in the general meaning of the word. So that is why our learners can't do it on their own.

M: The text book raw?

T2: Not that they can just be given the textbook. A lot of work needs to be done on top of the textbook the concepts of physical science is just unique and in sketches, helps a lot to show this and this and this they can see those forces and the direction of the forces

T1: and study and master doesn't have it a lot...sketches...and in Oxford there are some...Kagiso doesn't have enough sketches of which learners can understand what is involved.

M: the sketches are very important? Must be clear?

T1: the sketches are very important to integrate what they've read. The question is written in notes, only words, after that they must make sketches and then it is easy for them to calculate what is actually in the question. So, if there are no sketches in the textbook and that way of analyzing and to get into their knowledge (ie: to teach them) it is too difficult for our learners

M: what makes a textbook more accessible is the background knowledge the learners have...do you find there is a problem when they're coming from grade 9 into grade 10?

T1: yes a lot!

T2 : I think that in grade 9 here at our school...we have lots of grade 9's, from classes a to i and you notice that some of the teachers teaching natural science...we just grab the teachers just to fill in the timetable (ne)...and the teacher is comfortable with the life science and will dwell on the life science a lot and the learners, most of them...and we don't really guide most of them to take physical science, at times we do look at their potential and all that but some of them come from outside and we notice that learners know a little, very little about science. And then you notice that in grade 10

you introduce what was supposed to be done in grade 9 and then you see that there is a gap. And you as a teacher find that you must work really hard to help.

M: The textbook is assuming that the background knowledge is known....

T2: yes and in grade 10 these learners come from various schools, where various textbooks have been used and then when they come here now you notice that what you think they are supposed to have knowledge about , you might be disappointed

T1: another thing. I've just seen a grade 9 Focus textbook. It is a lot of physics and chemistry in that textbook...it is not long since I've seen that. In many textbooks the part of physics and chemistry is very little. Even in the work schedule: very little. For instance for this term and next term, it is only electricity. Most part of physics is not there, life sciences is there...the most when it comes to grade 9. So now when they go to grade 10 they are playing with many things which are different, which is a problem

T2: at some stage you notice that for example that in grade 10 going around these textbooks: Study and Master, Spot On and Physical Science for All...but Spot On is a little bit good but I cannot say that it is that good because you notice that in Study and Master one thing is explained clearer than it is in Spot On and a portion of that chapter in S&M is clearer than that other chapter in another textbook. You cannot as a teacher work on one textbook alone you must work on four

T1: or five different books

T2: Yes. Because some of the texts, even you as a teacher need to verify what and what was said before you take it to the learners. You cannot say that one textbook is 100% because one textbook is good at this and another one good at that.

M: financially...you have to choose...which can be a problem?

T1 & T2: yes...yes...

M: Another thing is whether a learner will engage with the text is their motivation...how do you find your learners? Are they motivated or must you work on their motivation?

T1: I think that the motivation must start from grade 8 and 9. Because when they go to physical science classes, even to choose that class, they have that negative attitude that the subject is difficult. Although they didn't prove it to them that they've done that subject and prove it: this subject is difficult. Now the grade 9's they are afraid of taking physical science as a subject they said, no it is a difficult subject I said no it is nothing like that it needs a hard working person...a hard working person, a person who's responsible...working hard. All that, all that package. For that person is not a difficult subject. So it must be worked back from grade 8 and 9 then you can have a chance in grade 10

M: yes..yes...I find it interesting that you said to me that sometimes the questions in the textbook are not close enough to the kind of questions they are going to ask in the year end paper..

T2: ja...ja...

T1: they are totally different...if you as a teacher rely on the questions that are set in the textbook you will notice that their standard is far, far below...

T2: very, very low. That is true.

T1: you can just use those questions just to make assessments but not to say you will rely on the standard of the textbook

M: you enjoy the glossaries? That is important to you...

T1& T2: yes...yes...yes...

M: the diagrams...

T1&T2: clear...important...

M: you mentioned that there was no textbook that was right but you did say that SM...

T2: It is difficult. Study and Master is easy for those gifted, those who are not gifted, it is too difficult.

M: We need to be looking after our not gifted learners...our technicians...electricians...

T1&T2: agreeing...

T2: you know what else can help our learners...to have a summary book that goes with the textbook. Not like exam bank with the previous question paper...that is okay. But a book that will summarise..like Olivier (the green and blue one)...that textbook is good. That textbook is good for the learners because it is simplified...although it has mistakes. There are many mistakes in that textbook and I don't know whether they have revised it now

That textbook is good. It helped our learners to enjoy the subject and engage in it.

M: Olivier was not on our recommended list...

(We then discuss "Cruising Science"...the workbook that is simple)

M: texts are sometimes tiring...

T1: You can get tired before you have even finished the paragraph. Only even two or three lines and it is enough and you take the textbook away.

T2: those learners that is what they are doing

M: to sum up...glossaries, summaries, clear graphics... Talking about more than one concept...

T2: that is fine if they work simultaneously. Sometimes there are two different concepts but they must work simultaneously.

T1: they must work together

T2: then they each have one answer although it is like that, they must know that it also happens that it also goes like that. Like two different equations that you must equate them and get one answer.

M: my findings have seen that a textbook often uses a difficult word where a simpler word will do. Like one textbook said “matter takes up space.” Another one: “matter occupies space”.

T1&T2 ...discussing and agreeing...possesses etc...

T2: another thing when it comes to grd11 and 12 organic chemistry, wow!! It is difficult for our kids and more especially when they take it to the lab and they ask a practical question involving organic chemistry and although they have done it in life sciences and also in chemistry class...organic chemistry...

M: teaching of organic...discussion...

T2: when I was marking...grammar is important. Organic chemistry is too difficult, is too difficult. Even the way they are questioning it. They don't just go for the simple things...like looking for alkanes...they go straight to the difficult part of organic chemistry.

M: do you think that a textbook that has too much...not so much extra...time that learners have to read and concentrate

T2: case studies...our learners have it difficult with the English. To read and to understand and all that stuff.

(general discussion....learning outcome 3, a problem with the language)

T2: there is another textbook. They use it in York. It is

M: mentioned Cruising Science. Made a note...the Mind Action series...

T2: yes...the mind action series. York is using that Mind Action series. It is also the right book for our learners when you give it to them it the book, the questions everything, the diagrams...I think that it is also working with Olivier textbook.

M: ...discussing what York shared with me w.r.t. cruising Science...

T2: then when we give our learners question papers they are used to answering questions like this

[M: thanking them for their time and all that they'd shared and outlining the procedure further]

Verification of Qualitative Textual Analysis

Verification 1

Your analysis of the first three paragraphs is absolutely spot on!!
They are completely beyond a novice learner of that age as well as being excessively boring....

Working memory overload is more or less guaranteed:

Language is complex and too many unfamiliar or new words

Too many conceptual ideas all jumbled together.

Utter incoherence of ideas.

Indeed, the distinction between mixtures and compounds is not an easy one and is best left to evolve with experience.

Physical and chemical separation is also a confused distinction and one not worth making.

If fact, one of the poorest pieces of scientific-educational writing I have ever seen!!

Verification 2

Just a few comments:

1) I agree that the sample text is an 'very good' example of really atrocious and entirely unsuitable expository discourse - for any learner, but especially for second/additional language readers, and even more so for those from disadvantaged backgrounds!

2) Your analysis is spot on, demonstrating clearly that the text is almost, if not completely, irredeemable. A more detailed critical analysis would, in my opinion, be superfluous, so I won't offer further comment.

3) I am not sure what your 'next steps' are, for the purposes of your dissertation For what it is worth though, your critical observations could be converted into very useful guidelines for either:
- What authors and editors should seek to avoid when preparing expository texts for second language readers; or more usefully
- 'How to' write and edit for this readership

I don't know if this is relevant for your work either, but if you are planning to make recommendations for the Education Department/publishers/authors/editors, it is really important to recognize that very often, even if an author has made a serious effort to write 'accessibly' and 'developmentally' - there are many systemic factors impacting on the writing, editing and production of textbooks.

Verification 3

Nice to hear from you again.

Yes, I would have to agree with you on your opinion concerning the readability of the Chemistry text. I don't know the level of English among your sample but I would say similar words on the complexity of the passage. The word used eg. matter is not consistent, the graphics /chart (mind map used) can be confusing as not all the links are described and even the terms used for describing the chemical change were never mentioned before.

APPENDIX D

A quick attempt at a draft re-write by Norman Reid

The World Around Us

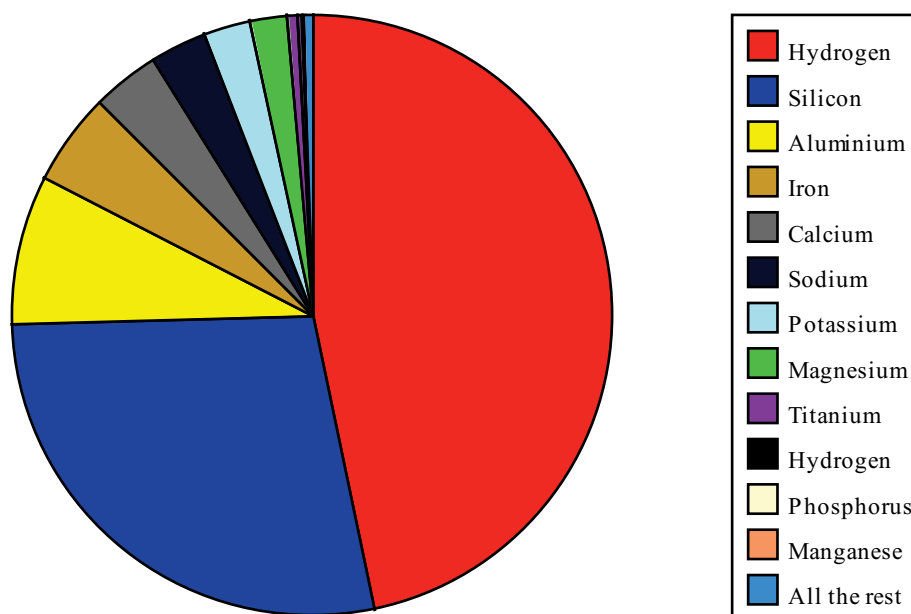
Have you ever wondered how the world around us is constructed. We are surrounded by all kinds of materials. We breathe a mixture of gases that we call the air. We drink water and there are other liquids like Seven-up, milk, petrol, and cooking oil. Then, there are all the rocks and sand that make up the world around as well as bricks, and things made of metals like cars. Of course, there is the food we eat and ourselves. We are made up of materials as well!

How can we make sense of all the materials around us? How is our world constructed and how do discover how to use materials and even make new materials? In one sense, the world is constructed in a very simple way. Over many centuries, groups of scientists called chemists started to realise that there are about 90 basic substances. Here is a way to think about it.

There are 26 letters in the alphabet (in English). Have you ever thought how many words can be made from these 26 letters? If you take even a moderate sized dictionary, you may well find 20,000 words listed. Amazing: 20,000 words from only 26 letters, and that is only one language. We make all the words by combining letters in various patterns and orders. Some letters are common, others are used much less frequently.

The world is made in a similar way. There are about 90 basic '*building blocks*'. The chemists call these the elements. Particles of these substances can link to each other to form all kinds of patterns and that gives rise to the huge variety of materials all around us. Some of these elements are very common, others are very rare. Oxygen is the most common one, followed by Silicon. Elements like Gold, Platinum, Mercury and Uranium are rare. That makes them more expensive. Because Gold has an attractive colour, it is used for wedding rings. Gold is soft and can rub away over the years. It is often mixed with other metals and the wedding ring is harder and will last longer.

It is possible to list the 12 most common elements:



Are there any surprises in the list?

Examples of how to make textbooks more "considerate" to their readers – Alistair Sharp

I would suggest therefore, that both the general language problems and the specific text organizational problems referred to by teachers could both be affected by weaknesses in rhetorical structure and that by making such structures more explicit, the textbooks would be making themselves more "considerate" and therefore comprehensible to readers.

Clearly, correctly selected vocabulary is vital in reading comprehension and recall, but the way a text is structured also plays a vital part and I would contend that this has been given too little emphasis in the preparation of textbooks by authors and publishers. The importance of making such rhetorical forms clear has been demonstrated in the research.

I would now like to offer examples of how suitable improvements might be made. Such improvements offer clearer signalling devices, titles, subtitles, introductions, topic sentences and make logical relationships more explicit. Some of the examples are taken directly from textbooks used in Hong Kong, others are adaptations considered typical of the kind of material found in school textbooks.

Example 1 : from a Hong Kong science textbook (Chan et.al. 1993, p65)

There are four chambers in the heart. The two chambers at the top are the collecting chambers: the left and right auricles. The two chambers at the bottom are the pumping chambers: the left and right ventricles.

Blood vessels carrying blood away from the heart are called arteries. Arteries branch into a network of fine tubes called capillaries. Their walls are so thin that exchange of materials takes place. Food and oxygen diffuse from the blood, through the wall of the capillaries into the body cells. Capillaries join together to form veins. Veins carry blood back to the heart. To prevent blood flowing backwards, veins have valves.

Alternative version

The Heart

1. The two chambers which **collect blood** are the left and right **auricles**
2. The two chambers which **pump blood** around the body are the left and right **ventricles**.

Blood Circulation

1. **Arteries** carry blood **from** the heart. These arteries branch **into** a network of narrow tubes called **capillaries**.
2. Next food and oxygen is **diffused** from the blood in the capillaries **into** the cells of the body. This diffusion, or movement, is possible because capillaries have very thin walls.
3. Capillaries join together to form veins. **Veins** carry blood **back** to the heart. To

*prevent blood flowing the wrong way veins have **valves**.*

The alternative version given here contains, more or less, the same content information, but has clearer signaling devices. Logical relations are made clearer by the use of **bold**, numbering and a more logical organization of meaning. (sequence and cause - effect relationships are made clearer) The text could, of course, be made even more "friendly" by additional elaboration: *Blood is forced into the arteries each time a ventricle contracts (becomes smaller) , you can feel the movement in your wrist when the arteries stretch and fill with blood. The stretching of the artery makes a pulse, Your pulse has the same rhythm as your heartbeat. The walls of arteries are thick and strong. Why? First, thicker walls are needed because arteries stretch with each pulse of blood. Thinner walls would break. Second, arteries assist in pumping blood.....*

Example 2

The life cycle of a butterfly

Butterflies lay eggs. The egg is the first stage in the life cycle. Caterpillars hatch from eggs. Not many of the caterpillars grow up to be adults. A caterpillar is the next stage of the butterfly - it is called a larvae. Caterpillars grow and eat a lot and when they get too big for their skin it splits. A new skin grows. The caterpillar grows on a leaf. This marks the beginning of the next stage of its life cycle. It changes into a pupa in a cocoon. Later the cocoon will open and a butterfly will come out.

Alternative version

The four stages in the life cycle of a butterfly

- 1. In the first stage the butterfly lays **eggs**.*
- 2. In the second stage the eggs hatch into small wormlike animals called **larvae**. The larvae grow and when they become big their skins split and fall off.*
- 3. In the third stage, the larvae become **pupae** . The pupae build a small case or compartment around them called a cocoon.*
- 4. In the fourth stage the pupae grow into adults, the cocoon splits open and an adult **butterfly** comes out.*

Once again the alternative version has made the structure of the information clearer and more explicit by a variety of signaling devices.

Example 3:

A chapter/book *Introduction* should give a clear overview of the content and structure that is to follow. If appropriate it should show the significance of the information to be offered, any cause-effect relationships or other logical structures.

Below is an example taken from a Hong Kong history textbook aimed at form 3 students. (Kan, 1996, p92)

Two major conflicts took place in the 20th century. The first one was the first World War (1914-18). It lasted for four years. The second one was the Second World War (1939-45). It lasted for 6 years.

(This introduction is followed in the textbook by details of the causes, results and events of World War 1, a description of political events after 1918, including the rise of totalitarianism, communism and democracy, followed by the causes, results and events of World War 2. None of this is mentioned in the introduction, nor is any clue given as to how the material will be organized.)

Alternative version:

*The first and second world wars **caused** great political and social changes throughout the world as well as being responsible for the deaths of millions of people. This chapter will look first at why these wars occurred and **how** the world changed **as a result**.. It will also look at some of the political ideas that developed, ideas such as democracy, totalitarianism and communism.*

The reader in the alternative version is provided with signals indicating the structure of the chapter that is to follow.

Example 4

Clarity of references may also make a difference. Does "they " refer to the people from the south or their ancestors in the example below?

The people from the south of the country learned from their ancestors. They were fishermen and warriors. They made tools and many fine buildings. They also traveled to distant lands. They wrote about their experiences.

Example 5

The use of analogy may also make the text more coherent by providing the reader with a suitable schema into which new information may be fitted.

Do you know how bread is made? Flour, water and yeast are mixed into dough. Then the dough is baked in an oven and the heat used to change the dough into bread.

The leaf of a plant use s a similar process. Just as the flour and yeast are used to make bread, so the water and carbon dioxide are used to make the leaf of a plant.. Sunlight provides the heat

Conclusion

Offering texts that are themselves more "considerate" will aid comprehension and recall. There is evidence that such "considerate" text will also increase vocabulary learning from context. (Gordon , et.al. 1992) .