A multi-theoretical analysis of the dynamics and effects of variation in the use of terms in school science textbooks in Nigeria and South Africa

By

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ABSTRACT

The performance of students in science subjects continues to be a source of concern in many African countries. In Nigeria and South Africa, one explanation frequently given has to do with students' proficiency levels in the medium of instruction and textbook publishing. Although several studies have been conducted from these standpoints, the issue of terminology variation within and across textbooks, and between textbooks and assessment tasks in English-language science textbooks, seems to be understudied. As a consequence, we do not know how terminological variation manifests, its effects on learners' achievement and the strategies learners can use to respond to it. Against this background, this study uses a multi-theoretical framework to examine the dynamics of terminology in Life Sciences textbooks in the context of learner's engagement with written science. The specific objectives of the study are to: (1) develop a typology of term variants in a corpus of Nigerian and South African high school life sciences textbooks; (2) establish the statistical distribution of term variants in selected Nigerian and South African textbooks; (3) determine the effects of terminology variation on learners' with different levels of proficiency in English language; (4) determine the effects of terminology variation on learners' with different levels of competence in science; (5) compare the performance of Nigerian and South African learners in tasks on how to identify and respond to term variation; (6) illustrate the relevance of thematic pattern in identifying and resolving term variation; and (7) propose and illustrate methods of teaching within content subjects in the sciences that address issues of terminology variation. The study is framed by Gerzymisch-Arbogast's (1996 & 2008) Context-specific Term Model; Lemke's (1990) construct of Thematic Pattern and Maton's (2014) Legitimation Code Theory(LCT)semantics. A mixed-method research design, combining quantitative and qualitative data and analytical methods, was adopted for the study. Data for the study was derived from three major sources. The first

source of data comprised text excerpts on ten topics derived from three Nigerian and South African high school textbooks on life sciences. The second source of data was the aggregate scores of learners in a test on identifying and resolving term variation (TIRTV). A third source of data was the audio recordings of the dialogue Think Aloud Protocols (dTAPs) which a subset of participants generated as they worked collaboratively in groups of three. The study sample comprised two hundred (200) high school learners in both Nigeria and South Africa. Seventy

(70) learners from two schools in each country wrote achievement tests individually. A further sample comprising sixty (60) learners, also from two schools in each country, wrote a test in groups of three. The performance of learners in the written test was analysed using Pearson Product-moment Correlational statistical test. The dialogue Think Aloud Protocols on the other hand were analysed using Interpretive Thematic Content Analytic (ITCA) technique. The results of the qualitative analysis of the use of terms in the selected textbooks indicated that term variants observed in the corpora can be classified according to three typological categories outlined in Gerzymisch-Arbogast (1996 & 2008), namely: contamination of similarity or Type 1 variation; contamination of inclusion or Type 2 variation and contamination of intersection or Type 3 variation. Results on the prevalence of the three typologies of term variants identified indicated an even distribution of term variants across the Nigerian and South African textbooks and a skewed distribution across the constituents of the clauses of both the Nigerian and South African textbooks. The results further indicated a negative correlation between language proficiency and achievement with a Pearson coefficient ($r = -0.9469$, $P < 0.05$) and a weak positive correlation with a Pearson coefficient ($r = 0.25495$, $p > 0.05$) between science competence and achievement. Results of the Interpretive Thematic Content Analysis (ITCA) of the dialogue Think Aloud Protocols further showed that learners could identify term variation

but lacked the requisite meta-linguistic strategies for responding to the challenge(s) posed by term variation. It was also found out that the practice of weakening the semantic density (SD-) of a term (e.g. solvent) by the use of a variant (e.g. water or liquid) facilitated the choice of correct answer by learners. A synthesis of quantitative and qualitative findings led to the following conclusions: a) term variation, which manifests as Typ1, Type 2 and Type variations, is a significant feature of Nigerian and South African life sciences textbooks; b) the distribution of the different typologies of term variants identified is proportional across the textbooks analysed but disproportional across the various constituents of the clauses of respective textbooks analyzed; c) term variation impedes learning (especially in assessment contexts) despite the language backgrounds of learners; d) term variation can be leverage through the meta-linguistic awareness that knowledge which terms encode are structured as waves of information. In view of these findings, the study proposed content-integrated terminology literacy in order to illustrate how learners can respond to term variation in their engagement with written science.

DECLARATION

I declare that the thesis titled 'A multi-theoretic analysis of the dynamics and effects of terminology in Nigerian and South African high school textbooks on life sciences' is an original work that has not been submitted to any University for any certification purpose. I further declare that all the works cited in the thesis are referenced and that no part of the work has been plagiarised from previously existing research.

Name of candidate: Richard A. Kamai Sign: _Kamai_   Date:10TH NOVEMBER 2017

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DEDICATION

This thesis is dedicated to Sir Kevin Saumam Kamai of blessed memory and Mrs Rose Hauwa

Kamai

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ABBREVIATIONS AND ACRONYMS

ABST: Arts Based School Type

BICS: Basic Interpersonal Communication Skills

CB: College Biology

CALP: Cognitive Academic Language Proficiency

CITL: Content Integrated Terminology Literacy

CLIL: Content and Language Integrated Language Learning

CSTM: Context-specific Term Model

DE: Downwards Escalator

DET: Department of Education and Training

dTAP: Dialogue Think Aloud Protocol

DUSW: Downwards Upwards Semantic Wave

ES: Essential Biology

FLS: Focus Life Sciences

ITCA: Interpretive Thematic Content Analysis

ISYP: Ife Six Year Project

LoTL: Language of Teaching and Learning

LLP: Limpopo Literacy Strategy

LCT: Legitimation Code Theory

MoE: Ministry of Education

NB: New Biology

NPE: National Policy on Education

OECD: Organisation for Economic Co-operation and Development

OSLS: Oxford Successful Life Sciences

PPMCT: Pearson Product-moment Correlational Test

PISA: Program for International Student Assessment

SBST: Science Based School Type

SF: Semantic Profile

SMLS: Study and Master Life Sciences

SACMEQ: Southern and Eastern Africa Consortium for Monitoring Educational Quality

SD(+): High Semantic Density

SG(+):High Semantic Gravity

SG(-):Low Semantic Gravity

SD(-): Low Semantic Density

HSF: High Semantic Flatline

LSF: Low Semantic Flatline

SW: Semantic Wave

TIMSS: Trends in Mathematics and Science Study

TIRTV: Test on Identification and Responding to Term Variation

TP: Thematic Pattern

TC: Term Contamination

UE: Upwards Escalator

UDSW: Upwards Downwards Semantic Wave

WAEC: West African Examinations Council

WCED: Western Cape Education Department

<div align="center">**CHAPTER ONE**</div>

<div align="center">**INTRODUCTION**</div>

1   Background to the Study

The current high rate of underachievement in science among high school learners in Sub-Saharan Africa has been the topic of much research (Okebukola & Jegede, 1991; Dzama & Osborne, 1999; Howie, 2003; Adeyemi & Adeyemi, 2005; Reddy, 2006; Probyn, 2006; Spaull, 2011; WAEC Chief Examiner Report, 2008; TIMSS, 2015; SAQMEQ, 2015). In South Africa, for instance, the Trends in International Mathematics and Science Studies (TIMSS) 2015 report indicated that the performance of learners is still at the low end, even though performance has improved since 2003. Reddy (2006) reported that the average science score for Grade 8 learners was significantly lower than the internal benchmark average. This finding is further corroborated by the Global Competitiveness Report 2015, which places South Africa at the bottom of the 148 countries assessed (Dutta et al., 2015; Schwab, 2015).

Adeyemi & Adeyemi (2005) reported that the performance of students in science at junior secondary school level in Nigeria has been low and that there has not been a single year where the performance level reached fifty percent in any Junior Secondary Certificate Examination. This finding is further supported by the 2008 Chief Examiners' Report on the Senior Secondary West African Examination which revealed that 83 percent of the candidates who sat for the examination that year failed to obtain the minimum five credits, with performance in English, the sciences and mathematics being especially poor (WAEC, 2008).

Several studies have been conducted to provide explanations for the poor performance of both Nigerian and South African learners in science (Fakeye & Ogunsiji, 2009; Aina & Olanipekun, 2013; Rollnick, 2000; Howie, 2003; Spaull, 2015). Discussions on underachievement in Nigeria and South Africa have traditionally been framed around a range of variables. First, there is the issue of the use of foreign languages in teaching science. The Ife Six Year Project (ISYP) 1970-1975 and the Limpopo Literacy Strategy 2004- 2014 were conceived to address this concern. But despite progressive policies by government to encourage the use of the mother tongue literacy, non-implementation of language policy recommendations is widespread, especially in government and independent schools. Bamgbose (1991) attributes this problem to the preference of some parents and school administrators for English language medium instruction, and fluctuations in language policy formulations by successive governments. In South Africa, lack of enabling legislation for implementing mother tongue literacy (Beukes, 2004), legacies of Apartheid (Desai, 2003) and lack of qualified teachers of indigenous languages (Manyike & Lemmer, 2014; Setati, 2012) have been identified as factors responsible for the non-use of home language as medium of instruction in science.

Secondly, there has been some discussion around the inequitable distribution of resources between schools in rural and urban areas. A World Bank (2005) study on the education sector in Nigeria reports a disparity in the allocation of textbooks, ranging from 80 per cent in Federal government funded schools to virtually no textbooks in some rural public schools. Concerning South Africa, Probyn (2006) reported that none of the six schools visited in a rural community in the Eastern Cape had received textbooks from the government for grade 8 and that teachers

share science textbooks to the ratio of three textbooks per class. This is viewed as a major factor responsible for underachievement in science in rural schools.

Thirdly, there is also the issue of large class size, which studies show can negatively affect the quality of teaching and learning science (Ogunmade, 2005; Boyi, 2014; Probyn, 2006; Marais, 2016). In Nigeria, Ogunmade (2005) reported a mean of 50 students per science classroom in both rural and urban schools in Western Nigeria, while Probyn (2006) reported a class size that ranged from 35-52 in rural science classrooms in the Eastern Cape region of South Africa. These figures have generally been associated with low-performing schools in a number of surveys conducted to determine learners' performance in science (PISA, 2012; TIMSS, 1999, 2003, 2007; SAQMEQ, 2015).

Fourthly, previous studies have suggested a significant relationship between the socio-economic status of learners and academic outcomes (Egunsola, 2012; SAQMEQ, 2011). In a study conducted in North Eastern Nigeria, Egunsola (2012) reported a statistically significant relationship among the following variables: parental educational qualification; occupation; home location; and students' performances in Science at secondary school. Similarly, the Southern and East African Consortium for Monitoring Educational Quality 2011 reported that students from the uppermost quintile, with a high socioeconomic status, far outperform students from the lower four quintiles in science achievement.

Fifthly, the relationship between language proficiency and academic achievement has been documented in various research studies in Nigeria and South Africa (Fakeye, 2014; Odili, 2012;

Ayodele, 2013; October, 2002; Dempster & Reddy, 2007; Maree et al., 2006). In Nigeria, several studies have illustrated how English language proficiency affects the performance of learners in science. This relationship has been explored in contexts such as the wording of assessment tasks (Odili, 2012) and learners' overall knowledge of English (Fakeye & Ogunsiji, 2009).The complexity level of the language of science textbooks has also been examined by studies on readability indexes (Ayodele, 2014). Several studies – e.g. Awofala, Awofala, Nneji, and Fatade (2012) and Fakeye & Ogunsiji (2009) – have been interested in the predictive value of proficiency in English with regard to the performance of learners in science.

South African scholars have explored similar themes, but from the perspective of the language of teaching and learning science, LoTL (Rollnick & Rutherford, 1993; Setati & Adler, 2000; Nomlomo, 2007; Planas & Setati , 2008; Howie et al., 2008), translanguaging (Olugbara, 2008; Hornberger & Link, 2012; Probyn, 2015); language learning strategies (Magogwe & Oliver, 2007), language proficiency (Cleghorn & Rollnick, 2002; Probyn, 2006; Howie, 2012, Cekiso et al.,2015) and scientific literacy (Laughsch, 2000; Reddy, 2006; Mji & Makgato,2006, Spaull,2015).

Findings of studies by Nomlomo (2007 & 2014), among others, point to a positive correlation between the use of the learner's mother tongue and academic performance in science. In other words that, the non-use of home language in science instruction impacts negatively on learners' achievement in science. On studies conducted on the interrelationship between language proficiency and science achievement, results of South African studies, e.g. Howie (1994),

Probyn (2006), Cleghorn & Rollnick (2002) and Cekiso et al. (2015) coincided in finding that language proficiency is positively correlated to academic achievement in science.

Studies by Laughsch (2000), Reddy (2006), Mji & Makgato (2006) and Spaull (2015) on the other hand, associate underachievement among South African learners in national and international assessment with poor scientific literacy skills. It can be seen from the above findings that, in both Nigerian and South African contexts, a similar challenge (underachievement in science) is viewed from different standpoints (language proficiency, use of home language in instruction and scientific literacy). It can also be noted from the studies cited that, while the language correlates of science achievement are diverse, the scope of what constitutes language proficiency is not all-encompassing.

1.1 Statement of the problem

Although attention is increasingly being directed at research on language as a factor of achievement in science in Nigeria and South Africa, very little of this focus is on terminology variation in English-language science textbooks and its effects on learners' performance. Previous research on the impact of language proficiency on academic achievement (Awofala et al., 2012; Fakeye, 2014; Maree et al., 2006, Demster & Reddy, 2007) failed to consider the processing of variant terminology as an issue. This is regrettable considering: (1) the terminology component in scientific texts can be very high and can impact on text intelligibility and readability (Antia, 2014; Doidge,1997); (2) in anyone country, there are several recommended textbooks for specific school subjects, and these different textbooks may not all use the same terminology (Kuecken & Valfort, 2013); (3) variation in terminology has indeed been documented in science textbooks (Evans, 1976; Antia & Kamai, 2006; Antia & Kamai

2016; Glewwe, 2009); (4) in both Nigeria and South Africa, the terminology in question is in English which, although not the home language of a majority of the learners, is the language in which most science textbooks are published or made available to learners (Edwards & Ngwaru, 2011; Aina et al., 2013).

The phenomenon of terminology variation can be illustrated using data from Lemke's (1990:87) analysis of a transcript of a geography lesson, even though our concern is with variant terminology in English language life sciences textbooks. On the first day of a lesson, the teacher uses the term 'Fossil'. On a second day, while revising the previous day's lesson, she or he uses another term 'Marine Fossil'. During the conclusion of the lesson, the teacher says 'Fish Fossil'. In the context of written textbooks, rather than classroom lessons, the effect of such variation has not been extensively studied. As a consequence, our knowledge is relatively inadequate with respect to how term variants manifest in science textbooks, what the effects on performance of different learner profiles are and what needs to be done to address any observed problems posed by terminology variation in learners' engagement with the science content of their textbooks.

1.2   Study aim and objectives
The thesis examines variation in the terminology employed in a corpus of Nigerian and South African high school life sciences textbooks. It has the following specific objectives:

(a) to develop a typology of term variants in a corpus of Nigerian and South African high school textbooks;

(b) to establish the statistical distribution of term variants in the Nigerian and South African textbooks;

(c) to determine the effects of terminology variation on learners' performance with different levels of proficiency in English language;

 (d) to determine the effects of terminology variation on learners' performance with different levels of proficiency in science;

(e) to compare the performance of Nigerian and South African learners in tasks on how of identify and respond to term variation;

(f) to analyse patterns of cognitive processes in learners' responses to test questions on how to identify and resolve term variation;

(g) to propose methods of teaching within content subjects in the sciences that address issues of terminology variation.

1.3   Research questions

The study was guided by seven research questions in line with the seven objectives of the study stated from the outset. The research questions include:

(a) What types of variant terminology are to be found in the Nigerian and South African Life science textbooks?

(b) How widespread is variant terminology in Nigerian and South African life science textbooks?

(c) What is the significance of language proficiency to the achievement of learners in test on identifying and processing variant terminology?

(d) What is the significance of science competence to the achievement of learners in test on identifying and processing variant terminology?

(e) Is there a significant difference in the performance of Nigerian and South African learners in test on identification and processing variant terminology in life sciences textbooks?

(f) How can observed patterns of cognitive processing of term variant be explained theoretically?

(g) What teaching and learning methods can be used to address any observed challenges posed by variant terminology in science textbooks?

1.4   Research hypotheses

Three null hypotheses were formulated to address research questions (c), (d) and (e) of the study. The three research hypotheses formulated were:

$H0_1$: There will be no significant correlation between learners' English language proficiency and their performance in tasks on identifying and processing variant terminology in life sciences textbooks.

$H0_2$: There will be no significant relationship between learners' science competence and their performance in tasks on identifying and processing variant terminology in life sciences textbooks.

$H0_3$: There will be no significant difference between the performance of Nigerian and South African learners in tasks on identifying and processing variant terminology in life sciences textbooks.

1.5   Significance of the study

a) Findings of the study can provide a fine grained account of the pedagogic functions of term variation in specialized texts. Furthermore, the exploration of the dynamics of terminology at the clausal level of analysis as opposed to the whole text or a page provides additional insights on the distribution of term variants in specialized texts.

b) In the past, terminology load, among other variables, has been used as a basis for determining the readability indexes of school textbooks. Findings of the study on the nature of knowledge types encoded by terms can revolutionize textbook appraisal previously carried out on the basis of aggregate terms in disciplinary texts.

c) The study will contribute to discourse on how to address the problem of underachievement in science in high school in African countries. This is imperative at a time when recent statistics rate African countries significantly low in the international high-performing benchmark average and significantly high in the international low-performing benchmark average (TIMSS, 2003; 2007, 2011).

d) The findings of the study will also provide a further rationale for broadening the scope of language proficiency/competence. It will also open up further areas of research on the nature and scope of scientific literacy. The former benefit resonates with the claim by Cummins that language proficiency is not a homogenous construct (See. Cummins, 2000, 2008). The latter, on the other hand, fits into the broader notion of scientific literacy which comprises "capacity to detach science-specific cognitive processes and knowledge from one situation and apply it to scientific problems" (Kauertz et al., 2012:714).

e) Although it is not practicable to recommend that all term variants in science textbooks be expunged because they tend to make the transition from one textbook to another difficult (Evans, 1976) or disrupt reading comprehension (Snow, 2010), textbook authors and curriculum

planners are likely to see the research as a call to implement quality assurance procedures around the use of terminology in school textbooks.

f) The content-integrated terminology literacy proposed and illustrated can be a teaching and learning paradigm that can be implemented in both Nigerian and South African classrooms. Likewise, the achievement test on identifying and resolving term variation, which has a Cronbach alpha reliability measure of (10 item test $\alpha = 0.70$), can be a tool that can be used to determine the scientific literacy or Cognitive Academic Language Proficiency (CALP) skills of learners.

d) Researchers in language education may find the results of the study useful to the development of a language-based theory of learning (Halliday, 1993; Rose, 2009). The teaching and learning strategies proposed and illustrated (i.e. transitivity analysis and thematic pattern analysis) can be useful for the design of literacy teaching methodology. Through this study, students can become aware of how knowledge is constructed and what linguistic strategy can be used to mediate content learning in scientific texts.

1.6   Outline of chapters

The study comprises eight chapters in whole. An overview of each of the chapters is given below.

Chapter One: Introduction

Chapter One gives an overview of the study in respect to the background and motivation for the study. It consists of the introduction, the problem statement, the aim and objectives of the study, the research questions and hypotheses guiding the study and the significance of the study.

Chapter Two: Literature review

The aim of the literature review is to clarify our understanding of term variation or lexical variation, and to argue that previous studies have failed to examine the phenomenon of term variation in language-oriented discussions on achievement in science. Thus, relevant and current literature on lexical variation and language proficiency are discussed in Chapter Two. The literature review is sub-divided into three sections: the first provides an overview of conceptual approaches to lexical variation; the second section discusses terminology and variation from the perspectives of textbooks and writing process; while the third section discusses academic achievement from the perspective of competence in terminology processing and language proficiency.

Chapter Three: Research methodology

The third chapter deals with the research methodology component of the study – specifically describing research design, specifying sources of data and describing participants. The chapter also describes the study area, sources of data and methods used for data analysis and interpretation. The ethical aspects of the research, and the code of conduct guiding the research, are also described in Chapter Three**.**

Chapter Four: Theoretical framework

Chapter Four elaborates on the three frameworks underpinning the study and their analytical components. The first theory is the Context-specific Term Model proposed by Gerzymisch-Arbogast (1996, 2008) while the second is Lemke's (1990) construct of Thematic Pattern. The

third theory underpinning the study is the Legitimation Code Theory proposed Karl Maton(See. Maton, 2013).

Chapter Five: Typology and distribution of term variants in Nigerian and South African life sciences textbooks: perspectives from terminology and legitimation code theory

Chapter Five addresses objective five of the study on the typology of term variants in Nigerian and South African life sciences life sciences textbooks and their statistical distribution of term variants across textbooks and clause constituents. Chapter Five therefore uses Gerzymisch-- Arborgast's (1996, 2008) Context-specific Term Model to develop a typology of term variants in Nigerian and South African high school life sciences textbooks. The chapter also uses descriptive statistics to account for the statistical distribution of term variants in Nigerian and South African life sciences textbooks. The chapter concludes with a section examining the pedagogic functions of term variation based on insights from the semantic dimension of legitimation code theory.

Chapter Six: **Significance of language proficiency and science competence to achievement in test on processing variant terminology**

Chapter Six discusses objective 6 on the impact of terminology variation on the performance of Nigerian and South African learners based on data derived from quantitative and qualitative sources. The chapter further compares the performance of Nigerian and South African learners to determine the cognitive impacts of term variants on the achievement of learners. The chapter concludes by sensitizing findings derived both data source to determine if results obtained from one methodological approach can be verified by results from another approach.

Chapter Seven: Teaching the dynamics of terminology in life sciences textbooks for high school: perspectives from terminology and systemic functional linguistics

Drawing from terminology theory and Systemic Functional Linguistics (transitivity and genre pedagogy), this chapter addresses the seventh objective of the study which sought to propose a pedagogy (content-integrated terminology literacy) for responding to term variation in life sciences textbooks. The chapter further illustrates how the proposed framework can be embedded into genre pedagogy to foster the optimal processing of knowledge encoded in science textbooks.

Chapter Eight: Summary, conclusions and recommendations

Chapter Eight summarizes the major findings derived from the quantitatative and qualitative methods adopted for the study. The chapter also outlines the conclusions drawn from the synthesis of the qualitative and quantitative analyses and profers recommendations to a range of stakeholders including learners, educators, authors and publishers.Chapter Eight ends with suggestions on areas for further research. In the next chapter of the study, current literature on lexical variation, terminology and language education will be discussed to clarify our understanding of term variation and to demonstrate that previous research on the languistic influences in science achievement has neglected the issue of term variation within and across textbooks, and between and across textbooks and assessment tasks.

CHAPTER TWO

LITERATURE REVIEW

2   Introduction

This section of the thesis reviews current and relevant studies in lexical semantics, text-linguistics and terminology in order to clarify our understanding of terminology variation. The first part of the chapter presents an overview of conceptual approaches to lexical semantics which for the purposes of the study are classified into three approaches: The formal approach which emphasizes the semantics or logical properties of lexemes as exemplified in Cruse (1986), Rosch (1999) and Kempson (1999). The textual-functional approach where the interest is in the cohesive harmony of words and the meaning potentials in patterns of lexis as illustrated in Hoey (1991) and Halliday & Hasan (2014). The terminology approach which explores the dynamics of terms as specialized text, which can be gleaned from the works of Temmerman (2000); Antia (2002); Bowker & Hawkins (2006); Rogers (2007); Schmitz(2007) and Gerzymisch-Arbogast (1996 & 2008).

The remainder of the chapter further discusses term variation from the perspective of textbooks and textualization (writing process) based on insights from studies conducted by Yong (2006), Prophet & Badede (2009) and Ayodele (2013). The last section of the review attempts a critique of the view that language proficiency is a correlate of science achievement and highlights the neglect of the issue of processing terminology in research on language in education.

2.1   Formal approach to the study of term variation: notions of synonymy

The earliest approach to the study of lexical variation is the formalist approach, which is noted for applying logic to describe the meaning of words and expressions. In this approach, words

and their properties are conceptualized based on set criteria or necessary conditions rather than dynamic or gradable attributes (Lyons, 1981; Cruse, 1986; Storjohann, 2010; Geeraerts & Kristensen, 2012). From this standpoint, Lyons (1977) describes lexical items whose senses are identical in respect of some central semantic traits as synonyms and classifies them into three broad categories: absolute synonyms, partial synonyms and near synonyms (Lyons, 1977,267). Lyons (1981) describes absolute synonyms as words that identical meaning and semantically equivalent in all contexts. In other words, for words to be described as absolute synonyms the words must have the same meaning and must be able to be used interchangeably in all situations. However, Lyons (1981) provides no example of absolute synonyms – possibly because absolute synonyms do not in fact exist (Danglli et al, 2009).

Lyons (1981) describes partial synonyms as lexical items that can be substituted with words with the same truth condition. Consider the words *fiddle* and *violin* in sentences 1a and 1b below.

   1a: She plays the violin

   1b: She plays the fiddle

Both words construe the same ideational content in the sentences they operate, but vary in that *fiddle* is a colloquial form of *violin*.

The third category is near synonym, which Lyons defines as "terms that can be paraphrased the same way, but not be felicitously used interchangeably in some context" (Lyons, 1981:267). What this means is that near synonyms construe identical reality or meaning but their use is limited to contexts. Lyons (1981) identifies the following variants as examples of near synonyms: 2a: Weep 2b: Sob 2c: Cry. A componential analysis of the variants exemplified in 2(a-c) will show that, while the words have different forms or structure in respect to their

orthographic measure, they all have to do with crying or shedding tears. The word *weep*, for instance, activates a sense of intense crying for a long period, while *sob* denotes crying that is accompanied with inarticulate sounds or speech.

Also motivated by formalist principles, Cruse (1981 & 1986) defines a synonym as lexical items whose senses are identical in respect to central traits but differ only in respect of what may provisionally be minor or peripheral traits. In other words, synonyms share some certain basic characteristics but differ in respect to some lesser important ones. Cruse (1986) categorizes synonyms into three distinct classes: absolute synonymy, cognitive synonyms and plesionyms.

Cruse (1986) also conceptualizes absolute synonymy based on the notion of ''relative normality'' of words – by which is meant words that could replace each other in any context. He states that "two lexical units would be absolute synonyms only if all their contextual relations were identical"(ibid, pp268). Cruse (1986:269) exemplifies absolute synonymy using the words *scandalous* and *outrageous* in sentences 3a and 3b that follow. 3a: That is a scandalous waste of money. 3b: That is an outrageous waste of money.

It can be seen here that the word *scandalous* in 3a and *outrageous* in 3b, can be used interchangeably in the context of money wastage because they activate the same meaning, involving an act that is grossly offensive to decency or morality. Danglli et al (2009) note that it would be very difficult to prove the existence of absolute synonymy, arguing that words like 'begin' and 'commence' can be used in the same context but that they do not have identical meaning in respect to Cruse's notion of relative normality because the former is informal while

the latter is informal. The general consensus on absolute synonymy therefore is that, it is either impossible, as argued by Lyons (1981), or very rare (Cruse, 1986), because it goes against the principle of language economy (Danglli et al, 2009). In order words, both Lyons and Cruse defined absolute synonym but provided no example while Danglli explained why no example of absolute synonym exist.

The second typology of synonymy identified by Cruse (1981) is cognitive synonymy, described as "a set of lexical item with identical truth condition but different forms and whose meaning depends on the propositional attitude expressed by sentences in which they operate" (Cruse, 1981:158). For instance,

> 4 a: I just felt a sudden sharp pain.
>
> 4b: Ouch!

The reality construed in the use of *pain* and *ouch* in 4a and 4b is similar in respect to their truth condition. In other words, both forms of expression activate a feeling of discomfort or hurt. The difference between both forms of expression is however in the manner they are both expressed. The former is expressed by utilizing language, while the latter is expressed by means of an attitude.

The third typology of synonym identified by Cruse is plesionymy – where lexical items have similar subordinate characteristics but their meanings activate different truth conditions. Examples of plesionym cited in Cruse (1981:158) are *fog* and *mist* in 5a and 5b below.

> 5a: Fog
>
> 5b: Mist

The lexical variants *fog* and *mist* share similar semantic traits by virtue of their location in the atmosphere. The truth condition associated with *fog* and *mist*, however, is not the same due to variance in the degree of condensation in the atmosphere. While both fog and mist are condensed water suspended in the atmosphere, mist refers to conditions of greater visibility, while fog is denser and results in decreased visibility(Narasimhan & Nayar, 2003; http://www.metoffice.gov.uk/learning/fog/difference-mist-and-fog). .

Due to recent advances in cognitive and corpus linguistics, the formalist approach to the description of the meaning of words and expressions has been criticized not only for its emphasis on the logical or semantic properties of words, but also for turning a blind eye to patterns of words that emerge from the use of synonymy in texts. The approach has however been fruitfully applied to terminology: for example, by Weissenhofer (1995) to develop a morpho-conceptually based classification system of English baseball terminology and by L'Homme (2004) to examine how lexical items are structured and captured in specialized texts. Despite these attempts, a further application of the formalist approach to description of lexical meaning has not been applied to the analysis of the dynamics of terms in specialized texts. The next section presents an overview of the textual-function approach which evolved to address the shortcomings of the formalist approach to the study of lexical variation.

2.2   Textual-functional approach to the study of lexical variation

The second approach to the study of lexical variation is the textual-functional approach, as gleaned from works of Halliday (1976) on cohesion, Hassan (1984) on cohesive harmony and Hoey (1996) on the pattern of lexis in texts. The textual approach evolved to account for the nature and use of lexical items in texts and their emergent properties and tendencies. The

textual-functional approach views lexical variation as a cohesive device or text property that contributes to the organization of discourse (Halliday, 1976; Halliday & Hassan, 1984; Hoey, 1991) with broad categories derived from empirical and observational data (Arppe, 2006; Inkpen, 2007; Storjohann, 2010). This perspective contrasts with the formalist approach which, as we noted, uses logic as a basis for describing the meaning of words and their properties.

From a textual perspective of meaning, Halliday & Hassan (1976) view cohesion as property of a text and categorizes it as comprising grammatical cohesion and lexical cohesion. Grammatical cohesion consists of reference, ellipsis, substitution and conjunction while lexical cohesion manifests as reiteration and collocation (ibid, p287).

2.2.1   Reiteration

Reiteration is the repetition of a lexical item or the use of a synonym of some kind in the context of reference (Halliday & Hasan, 1976:318) while collocation, which is the co-occurrence of lexical items, refers to all lexical relations that do not need referential identity and cannot be described as a type of reiteration (Halliday & Hasan 1976:287). Reiteration is further conceptualized by Halliday & Hassan (1984) as comprising full repetition and partial repetition. Full repetition occurs when two lexical items are similar in both form and meaning, while partial repetition refers to lexical items with different forms but with certain similar semantic traits. Examples of partial repletion include synonymy, antonymy, hyponymy, meronymy and general nouns.

2.2.2   Collocation

Collocation, on the other hand, refers to the co-occurrence of lexical items in a text or context (Halliday,1994; Stubbs,1996). Halliday (1994: 333) defines collocation as the tendency for

items to co-occur in a text, as a feature of lexical cohesion. In other words, it deals with words that tend to combine often. From a sociological standpoint, Stubbs views collocation as the tendency of words to co-occur with other words in their context (Stubbs, 1996: 172). Some examples of collocation are

The textual-functional notion of lexical variation has also been explored in Hoey (1991), whereby lexical cohesive devices initially proposed in Halliday (1976) and Halliday & Hassan (1984) are broadened to include grammatical and lexical cohesive devices. Thus, the typology of lexical cohesive ties described in Hoey (1991) comprises simple and complex repetition, simple and complex paraphrase, superordinates, hyponyms or hyponymy, co-reference, substitution and ellipsis. Under this typology, synonymy is viewed as simple repetition and is described as links – textual patterns or networks of repetitions of words that have similar meanings (Hoey, 1991: 265).

The potential interest of the textual-functional approach to my study lies in the insights it provides into the different ways lexical variation can be construed, and how they manifest in discourse. The next section briefly describes the theoretical underpinnings of the terminological approach and the research thrusts of studies conducted in the field.

2.3 Terminological approach to the study of lexical variation

This section reviews some studies by terminologists who are interested in analyzing the lexical characteristics of scientific texts with respect to the manifestations and functions of term\ variants in specialized texts. The variationist framework, as this interest or approach has been labelled (Daille et al, 1996; Daille, 2005), provides an alternative construal of synonymy in a

manner that is different from that of the formalist approach. This new approach has been applied in studies by Daille et al (1996), Carl et al, (2004), Antia et, al (2005), Daille (2005) and Tercedor (2011). Daille defines a variant of a term as an utterance which is semantically and conceptually related to an original term in three forms: 1) by a synonymy relation; 2) by reflecting a semantic distance from the reference term"; or 3) by a conceptual link (Daille, 2005

pp. 181-197). Whereas variants are sometimes understood as slight or formal modifications (clipped forms, acronyms/abbreviations of terms, word order variation, e.g. *flatbed colour scanner* or *colour flatbed scanner* (Bowker, 1997), term variation may refer to the use of hyponymns for hyperonyms or other forms of synonymy (Gerzymisch-Arbogast, 1996). The indeterminacy notion, as exemplified in Gerzymisch-Arbogast (1996), Antia et al (2005) and Antia (2007), views term variation as a concept indexed by any or a combination of the following: inconsistency, unpredictability, indefiniteness, vagueness, ambiguity, fuzziness, plurality, perspective, instability, slipperiness, etc. (See. Antia et al, 2005; Antia, 2007).

The terminological approach is also committed to the description of the quantitative tendencies of term variants in specialized texts. Gerzymisch-Arbogast estimates that the terminology load of disciplinary texts is somewhere between 20 – 25% of the total text (Gerzymisch-Arbogast 2008). Rogers' (2007) analysis of the use of terms in a trilingual glossary indicated the German text uses three synonyms and one hyperonym to describe a breathing device; the English text uses two synonyms and one hyperonym while the French text, which is the lexically most varied, uses five synonyms, three hyperonyms and one pronominal co-reference. Tercedor (2011) and Pecman (2014) estimated a figure within the range of 15% to 35% depending on domain, text types and kind of variants identified.

At the clause level of analysis, a study by Antia & Kamai (2016) found out that for each definition or explanation of a biology concept or term, a number of variants were used for the various constituents of the clause. In the explanation of nervous coordination for instance, the Actor, Process and Goal constituents of the clause are realized by three term variants each while the Circumstances alpha and beta slots are realized by two term variants respectively, making a total of thirteen variants out of fifteen terms used.

Research conducted within the terminology approach also outlined different motivations for terminological variation some of which are multidimensionality and perspectivization (Bowker, 1997 and Rogers (2004). Schmitt (2007) has pointed out the negative effects of variant terminology in software localisation context while Dialle (2005) and Carl et al (2004) have sought to provide a typology of term synonyms. Much of the above studies have been conducted in fields such as information technology (Ibekwe-Sanjuan & Sanjuan, 2004), monetary economics (Gerzymisch-Arbogast, 1996) and Biotechnology (Krauthamme & Nenadic, 2004). Having discussed the theoretical underpinnings and research thrusts of the terminology approach to the study of lexical variation, let us now turn to studies that explore the lexical characteristics of scientific texts with respect to the manifestations and functions using the terminological approach.

A considerable number of studies have been conducted on the lexical characteristics of specialized knowledge texts in respect to the typology (Daille et al., 1996; Jacquemin, 2001: 163; Carl et al., 2004: 107; and L'Homme, 2004: 78) and motivations /causes of term variation

(Bowker, 1997, Bowker & Hawkins, 2005; Antia, 2002; Rogers, 2006; Freixa, 2006). Working within the context of computer assisted translation systems, Daille (2005) identifies graphical variation, e.g. s*elflicking and self-licking refractory*, shallow syntactic variation, e.g. *column chromatography* and *chromatography on column,* syntactic variation *protein vegetable* and *protein of vegetable origin,* morpho-syntactic variation *rot after harvest* and *post-harvest rot,* paradigmatic variation *fuel expended* and *fuel depletion* and anaphoric variation where there is a previous occurrence of a base term in a text e.g. the use of *food process* to refer to *food fermentation process* if the later has been previously used.

From a similar standpoint, Carl et al (2004) examine term variants in an aligned English-French corpus based on the framework of Daille et al (1994) and Jacquemin (2001). The following typology of term variants were found in their corpus; omission, e.g. *supervised safety precaution and safety precaution,* insertion, e.g. *prone position* and *prone supported position*, permutation *sniper rifle rifle butt* and *butt of a rifle*; coordination *visual acuity* and *visual ability* and *acuity*; synonym *spotting telescope* and *spotting scope* (Daille et al., 1994; Carl et al., 2004). Let us now turn to some studies that highlight the motivations/causes of term variation in specialized texts.

Term variation has also been studied from the standpoint of the motivations and causes of lexical variability in specialized texts (Bowker, 1997, Bowker & Hawkins, 2006; Freixa, 2006). Bowker's (1997) study on multidimensionality of terms in the domain of optical scanning technology identifies perspectivization as the motivation for term variation. The study explores how a scanner can be described from either the perspective of colour or design. When the

perspective is that of design, the term is *flatbed colour scanner* and when it is that of colour, the term is *colour flatbed scanner*.

Bowker & Hawkins (2006) further observed that term choice in medical texts is motivated by conceptual motivation, i.e. linguistic motivation – the formation of words by combining elements of a term in a different order e.g. *cardiovascular* and. *vasculocardiac.* With respect to causes of term variation in specialized texts, a study by Freixa (2006) suggests that term variation arises in response to different linguistic needs, citing discursive, dialectal, functional, inter-linguistic and cognitive causes as some examples. This thesis adopts the terminological notion of lexical variation where the use of synonyms is seen as motivated. The terminological notion is also preferred because of the insights it gives on the manifestations and distribution of term variants in specialized texts. The next section provides a perspective on term variation textbooks and the writing process.

2.4 Terminology and variation: perspectives from textbooks and the writing process This section discusses the issue of terminology variation in the context of science textbook

authorship and texualization, or the writing process. I argue in this section that, previous research on the vocabulary component of specialized texts conducted from the three approaches described earlier, has neglected the issue of term variation within and across science textbooks, but has rather given more attention to textbook readability and readability formulas**.**

Although a large number of studies have been conducted on the vocabulary component of science textbooks, many such studies give emphasis on the readability of textbooks and readability formulas (Yong, 2006; Prophet & Badede, 2009; Ayodele, 2013). The issue of

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terminology within and across textbooks, and between textbooks and assessment tasks has not been adequately explored, as can be seen from subsequent reviews. Yong (2006) examines the relationship between readability of science textbooks and the reading ability of secondary school students in Brunei Darussalam. The reading levels of 48 Grade 7 students were measured by a cloze test. Then the readability of a senior secondary science textbook used in Brunei was determined by the Gunning, Fry and Flesch-Kincaid indexes. The results showed that the reading age obtained by the Gunning and Fry formulae is 15 while those of Flesch-Kincaid is 13, suggesting that Secondary School Science Book 1 has a reading level of 14.3 (the combined average of the three indexes). The analysis of the correlation between the students' reading level and achievement in science indicated 0% for student reading at appropriate or independent level, 0.3 % for student reading at instructional level, and 0.7 % of the students were found to be reading at the frustration or difficult level. The major thrust of this study is to determine text variables that foster or hinder the optimal processing of scientific text; it does not address term variation which may obfuscate the meaning of words in science textbooks.

Ayodele & Olagoke (2013) compares the readability of three Biology textbooks recommended for use in Nigerian secondary schools to determine whether the comprehension levels of the Biology textbooks are below, at or above the readability levels of the textbooks. To achieve this, the Flesch Reading Ease Formula was used to determine the readability indexes of the three Biology textbooks. The reading ability of 108 randomly selected senior secondary school students from classes 1-3 from six schools was determined, based on a cloze test which was administered to the students. The results showed a Flesch Index of 45.1, 59.2 and 43.3 for books one, two and three. When compared to the Flesch Readability Formula where zero (0)

corresponds to the very difficult reading and 100 corresponds to the very easy readability indexes, the Biology textbooks presented to the students in Senior Secondary 1-3 are fairly difficult and not appropriate for them. The study concludes that textbooks given to students should be at par with their grades and comprehension levels. The emphasis in this study is on the determination of the readability of Biology textbooks through assessing the reading comprehension of learners. It is not clear whether the readability formula (Flesch Reading Ease Formula) also tests learners' ability to identify and resolve terminology variation.

Prophet & Badede (2009) investigate whether simplifying the readability of junior certificate science examination questions would have a positive effect on learners' achievement in science. Learners from six junior secondary schools in Gaborone, Botswana were selected in order to participate in the study. Previous test questions derived from the junior secondary school science examination were modified by changing the length of words, tense and sentence structure of the test questions. A group of learners were administered the test questions in its original form while a subset of learners were administered the modified form. The study concluded that, the wording of test questions in science examinations at the Junior Certificate level does affect the performance of students and that, simplifying various linguistic factors in questions does improve performance significantly.

It can be noted from the above review that the major thrusts of studies conducted on the vocabulary component of specialized texts foreground the issue of terminology load to the neglect of how terms vary within and across textbooks, and between textbooks and assessment tasks. A consequence of this neglect is that our knowledge of the effects of term variation on

learners is still inadequate. We also do not know the specific strategies learners can use to respond to the challenge pose by term variation. From the standpoints of complex systems theory and legitimation code theory (LCT) semantics, on the other hand, these accounts of the terminology components of science textbooks are incomplete because they do not take into account the dynamics of meaning-making (Kageura, 2000; Kauffman, 2000; Maton, 2013). The next section reviews a number of studies that underscore the importance of terminology in science textbooks.

2.5   Importance of terminology in textbooks

I argued in the previous section that many studies conducted on the readability of textbooks have neglected the issue of terminology variation in textbooks. In this section of the chapter, an attempt is made to underscore the point that terminology variation is an issue in previous research on high school science textbooks. To support this claim, some relevant international and local studies are reviewed to illustrate the point.

Evans (1976) examines the treatment of technical vocabulary in six ordinary level biology textbooks in the United Kingdom. Unique terms in individual textbooks and those common to all the textbooks were identified and counted to determine their distribution. The results showed that textbooks employ considerable number of synonyms between and within textbooks. Examining specifics, individual terms had higher quantitative tendencies and were found to be mostly synonyms and stylistic variants, while the common terms on the other hand were not synonyms but were both explained and emphasized at their first appearance. Based on the above findings, the study concludes that the use of technical vocabulary in science textbooks would

be more effective if synonyms were eliminated because synonyms increase vocabulary burden and make it more difficult for a pupil to transit from one book to another.

Yager (1987) also examines the pervasiveness of synonyms in science textbooks used in the United States. Twenty-five of the most commonly used textbooks in K-12 science classrooms were analyzed in order to determine the occurrence of technical words. The results showed that the number of terms introduced at every level of schooling is higher than would be required if a new language were being introduced. The results further showed that the number of new terms exceeds the total vocabulary a learner would have been exposed to at a given grade level.

Groves (1995) analyzes secondary level science textbooks in Physics, Chemistry, Biology and Earth Science in order to determine their vocabulary load Index. To achieve this, selected narrative passages of half a page or one page length were identified in the selected texts. Scientific terms in the narratives from the selected texts were also identified. For reasons of precision, only word types were identified leaving out word tokens. Meanwhile, introductory materials, pictures, charts, graphs, figures, question problems, glossaries, indices and appendices in the textbooks, were excluded. The results showed a measure of lexical load of 2,950 in Chemistry; 1,899 in Biology; 1,538 in Physics and 992 in Earth Science. Although these estimates do not match Yager's (1983) lexical load index where, for instance a high measure of 2,173 is recorded for the Physical Science textbook, both studies conclude that the vocabulary load of science textbooks is higher than the grade levels for which they are targeted, and that heavy use of scientific terminology can impede learning and contribute to science avoidance by secondary school students.

Fang (2006) examines the functions of nouns and nominal structures in the construction of knowledge and the challenges they present in the comprehension of academic texts. Three sample texts in the academic subjects of language arts, science, and history at the elementary and secondary levels were analyzed and the structures of nominal expressions and challenges that nominal elements present in the three sample texts were described. The results identify nominalization as the pervasive feature of the science textbook. The study concludes therefore that the use of a noun or noun phrase to express meanings that might more typically be expressed in a verb, adjective, or whole clause can undermine a text's comprehensibility and the level of reader interest and engagement.

Asaishi & Kageura (2016) examine the growth of terminology in junior-high and high school Japanese science textbooks on physics, chemistry, biology and earth science. To achieve this objective, the mode of deployment of terms in selected textbooks was analyzed and a terminological network indicating the size, scope and the contiguous nature of term relations was developed. The results show that the average number of terms that are directly related (i.e. synonyms) are more in high school textbooks than in junior-high school textbooks in all domains except physics. The results further show that terms are indirectly connected through a few terms on average and strongly connected in partial groups in all the textbooks irrespective of domain and school level.

In South Africa, several studies have been conducted on the terminology load of science textbooks (e.g. Letsoalo,1996; Doidge, 1997). The study by Doidge (1997) examines the

readability of South African biology textbooks. The results show that that the textbooks analysed are opaque and not very accessible to learners. Letsoalo (1996) analyzes terms related to the breathing mechanism in a biology textbook used by Grade 12 learners in Lebowa, South Africa. The results show that the sentence structures, vocabulary, word structures and logico-grammatical structures in the Biology textbooks analysed are not suitable for the EL2 learners at Ramatau Secondary School in Lebowa, Northern Sotho. It can be seen from the above studies reviewed that the analysis of the vocabulary component of science textbooks is a major thrust of the studies reviewed. The next section discusses the issue of terminology variation within the context of text authorship.

2.6 Terminology variation and text-authoring

The previous section reviewed a number of studies from terminology, language and science education to underscore that fact that terminology load variation is an important issue in previous research on the vocabulary component of specialized text. This section is concerned with the motivations for terminology variation resulting from text authoring. We shall show that terminology variation in specialized text results from a range of factors, including (among others): textualization or authoring (Gerzymisch –Arbogast, 1996 & 2008; Antia, 2000), epistemological growth in disciplines (Temmerman, 2000) and perspectivization (Bowker, 1987; Bowker & Hawkins, 2005). Rogers (1996) illustrates how established systems shift meanings during writing using parallel texts from an English and German automotive engineering handbook. The results show that terms at the textual level are not constrained to one type of relation but may enter into many complex relations. The study concludes that terms are intra-lingually interchangeable labels in which context plays little or no role.

Gerzymisch-Arbogast (1996) analyzes a text on monetary economics to illustrate how the senses of terms at the system level, e.g. the dictionary or glossaries, do not always conform to the realisations at the parole level of the text. The analysis showed how a term, e.g. *money* and its synonym *cash* activate different senses ranging from medium of exchange to unit of account in the context of business transactions. Similarly, Antia (2002) uses data from legislative discourse to illustrate that the production of specialised texts is subject to the same constraints as the production of non-specialised text and that there is cultural relativity in specialized discourse. The results show that the sense of the term *legislation* in a legislative text changes as the text progresses. It at times means: *Bill, Act*, hypernym of both, or *Law*. A careful reading of the text, however, reveals that one can know which of these senses is being referred to by observing the prototypical collocates of the terms for each sense (e.g. *introduction* when the sense is Bill, *pass* when the sense is Act). Common to the study by Rogers (2006) and Antia (2002) is the idea that our understanding of texts can be enhanced by knowledge of how lexical items function in texts.

Antia & Kamai (2016) examines the nature of the use of terms in three high school Nigerian biology textbooks. The graphic and textual description of the process of nervous coordination were mapped on to a transitivity table specifying the type and token realizations of terms in the various constituents of respective clauses. The results showed that in the textual account, the Actor, Process and Goal constituents of the clause are realized by three (3) term variants each while the Circumstances alpha and beta slots were realized by two (2) term variants respectively making a total of 13 variants out of the fifteen (15) terms. Term variation was also pervasive in the graphic version in the Actor (2 out of 3), Process (2 out of 2) Goal (consistency), and

Circumstances alpha (2 out of 3) and beta (2 out of 3) making a total of 8 variants out of 15. This finding suggests that science textbooks are also prone to variation. The next section discusses the constraints and affordances of term variation in specialized texts.

2.7   Terminology variation in science textbooks: nuisance or resource?
The preceding section of the chapter described how term variation results due to textualization or the writing process. The aim of this section is to discuss the negative effects of term variation in translation, education and software localisation contexts.

2.7.1   The nuisance value of terminology variation
The nuisance value of term variation is illustrated in a study by Gerzymisch-Arbiogast (1996). The nature and use of terms in a specialized text on Monetary Economics was analyzed to demonstrate the challenges facing translators as lay decoders of specialist texts. Successive occurrences of terms related to money were observed, and each usage activates different senses not represented at the system or citational level. Results of the analysis showed that the term money is used at the textual or parole level as medium of exchange, unit of account, stock of value. The study concludes that the inability to identify the lexical and pragmatic function of terms as used in context may cause translation problem to inexperienced learners.

A study conducted from this standpoint by Antia & Kamai (2006) examines the effect of terminological variation on achievement in senior secondary school science in Nigeria. Specifically, the study sets out to test students' ability to identify synonymic relations within a given text and across texts on the topic nervous system. Will students be able to infer from the text(s), for instance, that:

(a) central nervous system (CNS) and brain and spinal cord are synonymous?

(b) impulse and information refer to the same entity?

(c) association neurone, connector neurone and relay neurone all originate from the brain?

(d) Nerve cell and neurone are synonyms?

Twelve students in their third year of senior secondary school who were randomly selected by their teachers to form four discussion teams of three members each were given a test. In a given exercise, the students had a specific textbook extract to read and answer some questions. The wording of the questions, that is the key terms, came not from one text extract, but from several texts treating the same topic and which students also had access to. The challenge here was to see if students would be able to match the linguistic environment of key words in a question (i.e. collocation, thematic pattern) with the linguistic environment in the reference texts in order to be able to identify synonymy. The results show that on several of the questions posed, students' performance was below 40%. In other words, the use of term variants had negative impact on the learners.

Rogers (2007) compares the use of terms in an introductory paragraph of a trilingual glossary on a breathing device. Results from the analysis indicated that the German text uses three synonyms and one hyperonym describe a breathing device; the English text uses (2) synonyms and (1) hyperonym while the French text, which is the lexically most varied, uses five synonyms, three hyperonyms and one pronominal co-reference. The study concludes that difficulties of mapping linguistic and conceptual categories within and across the three languages can pose a major problem to translators as lay decoders of specialized texts.

Schmitz (2007) examines variation of terms and icons in software localisation with the aim of demonstrating how term variation can lead to the problem of comprehension in translation contexts. some examples from the standpoint of terminology include the use of American analogies and metaphors shuts out other end users from other countries, e.g. *enter key* and *return key*; the use of semantically motivated terms e.g. *firewall, fatal error* and *illegal operation* the use of culturally misleading words, e.g. *deleting and tombstoning record* and *collaborators.* With respect to the use of variant icons, some notable examples of how variation adversely affects user's efficient interaction with software results when an icon does not show an appropriate object: e.g. *home* which in German means a different object, homonymy, e.g. *table* in English and *tisch* in German and homophone, e.g. *paws* in English and *pause* in German. The study concludes that non-transparent and variation of terms and icons lead to flawed communication and non-efficient interaction with software products.

Gerzymisch-Arbogast (1996) examines the nature and use of terms in a specialised text on Monetary Economics in order to demonstrate the challenges faced by translators as lay decoders of specialist texts. Successive occurrences of terms related to money were observed and each usage activates different senses not represented at the system or citational level. The study concludes that the inability to identify the lexical and pragmatic function of terms as used in context may cause translation problem to inexperienced learners.

It is in response to the nuisance value of term variation described in these studies that suggestions have been made to eliminate synonymy (Evans 1976) or quality assurance tools

have been developed, e.g. controlled language mechanisms are introduced to detect and correct varying use of terminology.

Antia & Kamai (2016) examine the effects of variant terminology on the performance of learners in an achievement task on processing variant biology in a reference text which uses a different set of terms from that in the test question. Fifteen (15) final year learners from a well-resourced secondary school in North Eastern Nigeria were assigned into groups of three and had to answer six questions (two from each topic) on nitrogen cycle, the cell and its environment and nervous coordination. The results indicated that the performance of learners was high (between 80% and 100%) on three questions and extremely low (13% - 30%) in the other three questions despite the fact that all topics were treated before the test was administered.

Thus far, an attempt has been made to show that terminology variation is indeed a problem in diverse contexts ranging from translation (Gerzymisch–Arbvogast, 1996, Rogers, 2007); education (Antia & Kamai, 2006; 2016) and software localisation (Schmitz, 2007). It is partly in response to these problems that, in some environments (especially safety critical), quality assurance tools, e.g. controlled language mechanisms or language tools that are constrained to carry out instructions based on sets of commands, are introduced to detect and correct varying use of terminology. Other suggestions to this effect from studies conducted in text-linguistics are that term variants be expunged (Evans, 1976) or that the terminology load of science textbooks be reduced (Groves, 1995). The next section will show how untenable it is to expunge term variants from specialized texts and how the dynamics of terminology in science textbooks can be leveraged to foster communication in specialized texts.

2.7.2 The resource value of terminology variation

We argued in the previous chapter that term variation can be problematic and illustrated the point by providing evidence from studies conducted in the field of software location (Schmittz, 2007), education (Antia & Kamai, 2006) and translation (Gerzymisch-Arbogast, 1996). In this section, we will consider the resource value of terminology variation based on insights from studies conducted in terminology and text-linguistics.

To begin with, it is worth recounting the view of Kope & Kalantis (2013), who argue that literacy in the 21st century should be one that also teaches learners how to negotiate diversity and variability of conventions of meaning in different cultural, social or domain-specific situations. The view by Maton (2013) that a measure of lexical variation is vital for knowledge building and of potential interest to teaching and learning science is also worth noting. It is in light of the forgone that the discussion in this section is anchored.

Bowker's (1997) study on multidimensionality of terms in the domain of optical scanning technology identifies perspectivization (i.e. the projection of a particular meaning of a concept) as a motivation for term variation. The study explores how a scanner can be described from either the perspective of colour or design. When the perspective is that of design, the term is "flatbed colour scanner", and when it is that of colour, the term is "colour flatbed scanner". Perspective is also evident in the study by Kaguera & Keita (1999) who examine the word structure of disease names in Japanese medical terminology. Results from the analysis of synonymous designations indicate that, for a given disease the relevant synonymous terms

convey different views of the disease, e.g. the part of the body affected or the mechanism of the disease, such that a nuanced or rounded picture of the disease can be understood.

Temmerman (1997) examines the functionality of polysemy and synonymy in molecular biology by illustrating how the use of terms (cloning, molecular cloning, DNA cloning and gene cloning) allows for evolution of understanding of the process amplification of DNA in genetics. The study also illustrates how the use of these set of variants e.g. *Southern blotting, Southern transfer and Southern hybridization* foster categorization and communication. The study further showed that these term variant activates different the methods and perspectives on the DNA sequencing ranging from the result of the amplification (a blot), the process of amplification (a transfer) and the principle underpinning the amplification(hybridization).

Besides the cognitive affordances which synonymy can provide in categorization and fostering communication, it has been found to be useful in the formation of semantic networks. To illustrate this point, Rogers (2003) examines the use of terms in an automotive engineering corpus on catalytic converter derived from a Mercedes-Benz website. The study identified instances of synonymy involving the use of *Katalysator* and *catalytic converter* and compared the relationship between a superordinate term *Katalysator* and subordinate terms *closed-loop*; *three way catalytic converter* and *catalytic converter*. The study concluded that lexical relations involving the use of synonymy and hyponymy in the corpus help in establishing cohesive links and building up explicit semantic networks which can be of benefit to translators and terminographers.

Rogers (2007) shows how patterns of lexical chains can form cohesive ties in a German technical text and in translations of the text into English and French. The study observes that the terms used as designations for *Ausatemsystemschalldamfer* (German), *muffling system* (English) and *valve d' aspiration de type silencieux* (French) vary not only within each text (intratextually) but also across languages (intertextually). For instance, the initial designation *Ausatemsystemschalldamfer* in German is used once while *Ausatemsystem, Schalldamfer* or *Gerat* are used subsequently. In the English translation, *muffling system* is used initially but later substituted with *device* or *exhalation system*. In the French translation, *valve d'aspiration de type silencieux* is substituted with either *silencieux dispositif, il, valve d'aspiration* or *produit*. The study reveals that, despite the complex network of terms operating within and between texts in relation to a central concept (a breathing device), functionality is achieved by the use of co-reference to build up lexical cohesion. In other words, knowledge that a well written text is necessarily cohesive provides a basis for considering these various terms as synonymous.

Antia (2017) examines synonymy as index of multidimensionality and knowledge anchor in the English and Afrikaans high school matric examination test questions. These claims were demonstrated by analysing variant terms used in setting matric questions on life sciences and agricultural science. Results from the analysis showed that, the English term *canine* has a synonymous pair in Afrikaans *oogtande/slagtande,* and that the synonymous pair provides cognitive affordances related to the function of the canine (i.e. ability to tear food and the location of the canine in the mouth (i.e. below the eye). In terms of the resourcefulness of synonyms as knowledge anchor, i.e. anticipatory meaning of a term, the study cites examples

of the terms *bipedal, incubator* and *DNA molecule* to illustrate how the Afrikaans doublets i.e. *tweevoetig/bipedal, broeikas/incubator DNS/DNA–molekuul* respectively, look like the English ones (note the similar orthographic measure) and are the more often used and can presumably make the meaning more transparent when jointly used. Based on these findings, the study concludes that synonymy is a language resource that can be leveraged to foster effective processing of information by learners in assessment contexts.

Lemke's (1990) study, though not in terminology, is also illustrative of the resourcefulness of term variation in a teacher talk. The study analyzed classroom transcripts in order to track how a teacher and his learners use terms related to fossils during a Geography lesson. The results showed that on a first day of the lesson, the teacher uses the term *fossils* to introduce the topic of the day. On day two while revising the previous day's topic (i.e. previous knowledge) he uses *fish fossils* and *marine fossils* instead of fossils. It was further observed that the teachers uses the terms ''moved'' (twice) and something' (once) to refer the verb. A relationship of synonymy between the variant terms used by the teacher can however be established by the meta-linguistic awareness that fossil is a superordinate term while marine fossils and fish fossils are refer to the same entity because *crust* is a clipped form of *earth's crust, land* is a synonym of *crust* and *it* is co- referential with *crust.* Lemke (1990) reckons that ability to make the above inferences and using them in making arguments and answering questions constitute what it really means to talk science.

The above studies reviewed describe the resource value of term variation as opposed to its nuisance value which was discussed in the section preceding this. The discussion was anchored

on the views of Kope & Kalantis (2013) and Maton (2013) who both argued that a measure of lexical variation is important for teaching and learning. I argue in the next section that language proficiency as defined in research on language in education is an inadequate framework for accounting for academic achievement in science, due to its inability to address the issue of competence in processing variant terminology.

2.8 Accounting for academic achievement: competence in terminology processing versus language proficiency

The preceding section of the study reviewed studies in terminology and text-linguistics in order to illustrate the resourcefulness of term variation. In this section of the study, we argue that, while there is a lot of research demonstrating the possible impact of language proficiency on academic achievement, very little work has been done on the issue of how learners can process variant terminology as a language proficiency issue.

The discussion in this section is divided into two parts. The first part discusses language proficiency as a factor of achievement in science based on evidence from Nigeria and South Africa. In the second part, an attempt is made to interrogate conclusions drawn from findings by language educationists based on perspectives form terminology and to argue that any conception of language proficiency in language education has to be based in part at least on the ability to process term variation as illustrated in the preceding sections of the review.

2.9 Language proficiency and academic achievement in science: Research evidence from Nigerian and South African learners

Several studies have been conducted on the interrelationship between language proficiency and academic achievement in science (October, 2002; Nomlomo, 2007; Mare et al, 2006; Awofala

et al, 2012; Odili, 2012; Aina et al, 2013; Fakeye, 2014). In this section, we review some Nigerian, South African and non-African studies which examine this relationship. Let us begin with Nigerian studies.

Awofala et al (2012) investigate the relationship between Nigerian students' performance in the senior secondary school certificate examination in English and performance in each of the basic Science Technology and Mathematics (STM) subjects (Mathematics, Biology, Chemistry, Physics, Agricultural Science and Technical Drawing). Three hundred and ten (310) secondary school students from eight (8) schools in Epe, Lagos state participated in the study. A Pearson product correlation test between the performance of students in English and the six science showed a significant positive correlation of ($r = 0.762; 0.582; 0.520; 0.591; 0.648$ and 0.588) for Mathematics, Biology, Chemistry, Physics, Agricultural Science and Technical Drawing respectively.

The study therefore concludes that learners' English language proficiency need to be scaled up to enable them perform optimally in science. This study treats language proficiency as a broad construct that is determined by the cumulative result of learners alone. The finding has not specified the entire variables that constitute language proficiency and whether ability to process terminology can be accommodated within the framework. Furthermore, limiting the scope of language proficiency to achievement scores only does not provide insights into the cognitive processes of learners during the test.

Odili (2012) compares the performance of selected Nigerian learners in a Multiple Choice Test whose items were presented in the original form of the language used by the West African Examinations Council (WAEC) in Senior School Certificate Examination (SSCE) and a parallel assessment in which the language of the test items was simplified. A sample of 1000 participants was randomly drawn from twelve urban and rural schools in Delta State, South-Western Nigeria. A test in the original language used by the examining body (WAEC) was administered to a group of students while another group of learners wrote a simplified version of the original test. The results showed that, 308 learners passed the test in the original test form while 337 learners passed in the simplified form. In other words, there were thirty-one (31) additional learners who passed the modified test than those who wrote the original test. Based on this finding, the study concludes that simplifying the language of test items is likely to address the problem of poor performance in science and increase the content validity and reliability of public examinations. While substituting the context-reduced academic language of examination with context-embedded language of social interaction is likely to foster achievement, the neglect of the ability to process term variation might likely result to greater achievement scores that the 3.1 per cent recorded by learners who wrote the simplified test.

A study by Aina et al (2013) investigates the correlation between proficiency in English and academic performance of learners in Science and technical subjects. A descriptive correlation analysis of the results of one hundred and twenty (120) advanced EFL learners, North Central Nigeria was carried out using a Pearson Product- moment Correlation Coefficient. Results of the analysis indicated a positive correlation between English Language proficiency and students' academic performance in science and technical subjects with correlation coefficient

of($r = 0.553 > 0.05$ and $r = 0.643 > 0.05$) respectively. In other words, the proficiency of learners in the English language can predict learners' performance in science and technical subjects. The argument earlier made on the use of cumulative scores of learners to gauge language proficiency is also applicable here. Thus, the strategies learners adopt, e.g. ability to process term variation, have been subsumed under a broader conception of language proficiency.

Fakeye & Ogunsiji (2009) examines the extent to which Nigerian secondary school students' proficiency in English predicted their overall academic achievement in two states in Western Nigeria. Four hundred (400) participants were proportionately sampled from eight secondary schools in Oyo and Osun states. An English Language Proficiency Test (ELPT) was administered to the respondents to determine their language proficiency levels. The achievement scores of the participants in the test and the aggregate scores of their annual performance in Mathematics, Biology and English were analysed. The results indicated a significant correlation between English language proficiency and academic achievements of the subjects studied with a coefficient of ($r = 0.499$). On the relationship between language proficiency and achievement, results of the regression analysis indicated a coefficient of ($FC (1,198) = 18.0; P < .05$) suggesting that that proficiency in English does have a significant impact on senior secondary school learners' academic achievement. Based on these findings, the study concludes that efforts should be geared towards making the Nigerian students proficient in English as a way of improving their academic performance. As argued earlier, language proficiency is viewed in previous studies as a homogenous construct that can account for all language variables related to learner achievement. These particular studies reviewed have

also not demonstrated how challenges which variant terminology poses may be simply or easily addressed by language proficiency.

South African studies have also explored similar themes but with greater emphasis on issues of race, geography of schools, resources, and specific languages (other than English). Guided by the South African National Quintile Index, October (2002) analyzes the performance of learners from different school categories in the Western Cape in order to determine the performance of African language speakers in comparison with their Afrikaans and English speaking counterparts. To achieve this, the matric results of 367 Grade 12 learners in the Western Cape Province were analysed. The results showed an average performance rate of 96. 85 per cent in schools that adopt English as Language of Teaching and learning(LoTL), 77.53 per cent in schools that adopt Afrikaans and 50.63 per cent of schools that use isiXhosa as language of instruction. The study therefore concludes that, the low matric pass rate among African language speakers (i.e.50.63%) in comparison with the better results obtained by their Afrikaans and English speaking counterparts (96. 85%; 77.53% respectively) is due to the fact that while English and Afrikaans learners are assessed in their home languages, Black learners are assessed in a second or third language**.**

Previous findings related to this conclusion are mixed and contentious: some show that home language instruction foster learner achievement (Bamgbose, 1991:9; Mare et al, 2006; Nomlomo, 2007); while other studies conclude that instruction in home language does not automatically result to achievement in science (Wilson et al, 2012: 3). In this regard, Antia & Kamai (2006) argue that learner achievement resulting from home language instruction can better be fostered if learners are taught how science functions in indigenous languages. One

aspect relevant to this is the ability to process term variation using thematic pattern which has not been addressed by October (2002).

Nomlomo (2007) reports the result of a three-year longitudinal study which examines the use of isiXhosa as a medium of instruction in the teaching of Science in two schools in Khayelitsha and Nyanga black townships in the Western Cape. One class which served as the experimental group in each school was taught science and geography in IsiXhosa while another, the control group, was taught using English language. The results showed that majority of learners in the experimental group (13) obtained more than 40%, which is the lowest pass mark. Three (3) of the learners obtained more than 50%, while 5 of them got more than 60%. The results further showed that majority of the control group learners (75% or 7 learners) failed the test i.e. scored below 40% and that only 8 learners) scored between 40% - 49% in the test. Based on this finding, the study concludes that the high performance observed in the experimental group is not unconnected with them being taught in isiXhosa. This study has also not also considered the processing of variant terminology as an issue despite the importance of terminology in science textbooks. In view of this fact, the critique of the study by October (2002) is applicable to this study.

Similarly, Olugbara (2008) investigates the effect of IsiZulu - English code switching in the teaching of Grade 10 Biology and the performance of the learners. Four high schools in Esikhawini and Kwa Dlangezwa, townships in the province of Kwazulu - Natal in South Africa, were randomly selected from the experimental groups (IZECS) and the control (EL) groups. The experimental groups were taught the human breathing system using isiZulu / English while

the control group was taught using English language. A biology achievement test, a questionnaire and classroom observations were used to collect data for the study. A pre-test and post-test experimental design was used to measure the differences in the performance and attitudes of the students, following the IZECS and EL interventions. The results of the analysis showed a pre-test of 6.81 and a post test of 10.78 for the group that was taught using IsiZulu and English code switching and 6.69 and 8.55 for the group that was taught using English Language respectively. In view of the significant mean scores of the group taught using IsiZulu and English in the pre-test and the post test, the study concluded that teachers should use IsiZulu and English in teaching biology. While this conclusion slightly varies from those reported in October (2002) and Nomlomo (2007), where the use of home language is viewed as the ideal model of learner achievement in science, it also neglected the issue of processing variant terminology in science textbooks as a language issue in the learning science.

Maree et al (2006) investigate the predictors of science and mathematics achievement in Mpumalanga province. Eight hundred and ninety-nine (899) Grade 8 and 9 learners from rural secondary schools in Mpumalanga completed a science and mathematics questionnaire which probed learner background, attitudes and classroom practices. A test was further administered to determine learners' knowledge and understanding of natural science and mathematics. A stepwise non-linear regression indicated significant differences between the performance of learners and achievement by language groups (r =11%), gender (r = 25%) and socioeconomic status (r =20%). With respect to language, the study concludes that black learners from the rural parts of Mpumalanga province are at a disadvantage because they have not acquired the scientific literacy considered essential for learners of their grades. The first finding is a marked

departure from the previous ones discussed in this thesis, but shares the relative neglect of the processing of terminology as a task in learning challenge. It is still unclear from the conclusion what the scope of scientific literacy entails.

Dempster & Reddy (2007) investigate the relationship between the performance of black learners in poorly resourced schools who have limited English language proficiency and learners in non-black schools who have better English-language proficiency. Both groups were exposed to the same curriculum but differed with respect to the quality of teaching they received, the availability of resources, and the level of functionality of their schools. The test questions were analysed based on seven readability factors: sentence complexity, unfamiliar words and long words, the use of passive voice, specialised terminology, length of question items, use of logical connectives and prepositions. The results showed that learners of African descent had difficulty in selecting the correct answer in most of the 73 TIMSS test items compared to non-African learners. Based on this inference, the study concludes that, participants with a higher science knowledge base and proficiency in the language of the test (i.e. English) recognize when they do not know the correct answer and make a random selection, while participants with lower science knowledge and lower proficiency in the language of the test use some strategy, albeit an incorrect one, to make their choice. Compared to both the Nigerian and South African studies reviewed, the conception of language proficiency adopted in this study is broader because it treats terminology and foregrounds learners' ability to process difficult texts text as an additional correlates of language proficiency. A major shortcoming of the study, however, is its inability to address the issue of processing term variants.

Internationally, a great deal of research has also been conducted on the effect of language on achievement in science. The studies reviewed below focussed on the significance of language proficiency to the performance of Mexican-American; Chinese in Australia and Indians in Britain. A study by Torres & Zeidler (2002) examines the effects of English language proficiency on the acquisition of science content knowledge among Hispanic English language learners in the United States. The language skills of seven hundred and forty five (745) Hispanic Grade 10 Earth Science, Biology and Chemistry high students were tested over a period of twelve weeks to determine their language proficiencies and track their language development. The study adopted a three-way factorial design consisting of three independent variables (i.e. English language proficiency, scientific reasoning skills, and students' classification as "language learners") and a dependent variable (scientific content knowledge). The results of the study showed that Hispanic English language learners in Grade 10 classified as having low English language proficiency scored the same on the standardized science test as Hispanic English language learners in Grade 10 classified as having a high English language proficiency. The study further showed that Hispanic English language learners in Grade 10 classified as possessing intuitive reasoning skills score the same on a standardized science test as Hispanic English language learners in Grade 10 classified as possessing reflective reasoning skills. This finding suggests that combined high levels of English language proficiency and reasoning skills enhanced students' ability to learn scientific content knowledge in English.

A study on how limited English proficiency Chinese high school learners understood the teaching of chemistry was conducted by Tobin & McRobbie (1996) in Brisbane, Australia, adopting a mixed method design which combined quantitative and in-depth interview of

respondents. The results from the quantitative analysis indicated a mean achievement of the limited English Proficient Chinese learners was not significant ($p < 0.05$) compared to the mean achievement of the 37 English Proficient Australian learners. Results from the responses of the Chinese learners interviewed on the other hand showed that despite the students' efforts to learn chemistry with understanding, they were limited by their poor proficiency in English. Based on these findings, the study concludes that the linguistic hegemony that fosters the use of English to teach chemistry and assess performance positions the limited English proficient Chinese learners as potential academic failures in science.

In a similar study, Duran et al (1998) examine how Mexican Americans interpret biology concepts using a social-constructionist theory to illustrate the interrelationship between proficiency in English and academic performance in science. Fourteen 14 grade 10 high school learners (8 females and 6 males) from an urban immigrant community participated in the study. Data for the study was derived from classroom observations, individual and group interviews and students' written reports. The results of the analysis indicated that learners deferred in their scientific interpretations of biology conceptions. The study concluded that providing language minority students with opportunities to acquire the language of science and other semiotic tools can go a long way in increasing student understanding of meaning-making tools in biology.

Thus far, evidence from the Nigerian, South African and international studies reviewed suggest that students' limited proficiency in English constrains achievement in science. In other words, that proficiency in English language is a factor of achievement in science. I shall, however, argue that since the processing of variant terminology is not specifically addressed in these studies, and because language proficiency is treated as a homogeneous construct, such claims

need to be cautiously interpreted in light of findings from research conducted in terminology insights from research findings on the Asian effect (Kyo, 1995) and trends in language learning theory (Cummins, 2000)**.** The next section of the chapter questions the conclusions of previous research on view that language proficiency is an indicator of science achievement in high school assessments.

2.10 Interrogating relationship of language proficiency and academic achievement in science: perspectives from terminology

The preceding section reviewed studies conducted in Nigeria, South African and internationally on the significance of language proficiency to the performance of learners in science in high school. We noted that, much of the research conducted from this standpoint coincide in finding that students' limited proficiency in English constrains their science achievement. In this section of the literature review, we shall question this claim in order to underscore how terminological competence may not necessarily be a part of language proficiency. To achieve this aim, findings of studies on the ''Asian effect'' reported in Kyo (1995) and Cummins' (2000) notions of Basic Interpersonal Communication Skills and Cognitive Academic Language Proficiency Skills are used as backings to the argument that ability to process variant terminology is beyond the scope of language proficiency as defined in previous research by language educationists.

Let us first consider studies conducted on the ''Asian effects'' in relation to the claim that language proficiency is a factor of achievement in science. There is ample research in language education that relates achievement in science in the high school to language proficiency (Arbeiter, 1984; Wong, 1990; Schneider & Lee, 1990; Peng & Wright, 1995; Fejgin,1995; Huang & Waxman, 1995). From the studies reviewed we see that some scholars have

questioned this claim citing research findings that portray Asian Americans as better achievers in maths and science than their Hispanic, non-Hispanic White and African-American peers who are perceived to be competent in English are also somehow unable to rely on this competence to see them through tasks associated with language use in academic settings. This therefore calls to question the findings of studies attributing language proficiency as a factor of achievement in science. It will also particularly be of interest for language educationists to find out what competencies such learners employ to mitigate the otherwise negative effects of language of instruction on their processing and understanding of science.

Language proficiency is extensionally defined in language education discourse as: ability to deal with LGP/LSP acceptations of lexical items (Audu, 2005); ability to differentiate between numeric problem and word problem (Henri et al, 2003); ability to identify technical terms and symbols (Maier & Schweiger, 1999) have been questioned as minimalist account of language proficiency. What that means is that, the scope of what constitutes language proficiency excludes a wide range of language and text analytical skills that learners need to process the knowledge encoded in science textbooks. Thus, a broader perspective of language proficiency which distinguishes between Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP) has been proposed by Cummins (2000). This distinction also challenges claim in previous research that learners with limited English proficiency (LEP) perform poorly in science and mathematics (Torres & Ziedler; 2002; Odilli, 2012; Demspter & Reddy, 2007).

As a response to the claim by Oller (1979) that all individual differences in language can be accounted for by just one underlying factor termed global language proficiency (1979), Cummins (1984) models language proficiency as continua comprising Basic Interpersonal Communication Skills (BICS). BICS describes the development of conversational fluency in a second language while Cognitive Academic Language Proficiency (CALP) refers to the development of language in academic context (Cummins, 2000).

In order to clarify the distinction, Cummins uses the metaphor of an iceberg situate each proficiency skill in its appropriate place. Such that, the region above the waterline represents basic interpersonal Communication skills (BICS) and is characterized language activities, e.g. pronunciation, vocabulary and grammar while Cognitive academic language proficiency (CALP) is situated in the deep region and is characterized by semantic and functional meanings of words. Insights from Cummins' iceberg model allow us to rationalize that competence in processing variant terminology may not necessarily be a part of BICS but can be included in CALP. From the terminology studies reviewed, ability to process knowledge encoded in terms would ideally belong to the deep level which requires analytical competence/meta-linguistics skills. Regrettably, the distinction between these two skills is blurred in the studies reviewed. What obtains rather is a wide range of meta-linguistic skills subsumed under language proficiency.

While subscribing to the view that the scope of what constitutes language proficiency in language education needs to be broaden and that Asian Americans learners (i.e. Chinese, Japanese and Koreans) are able to excel in scientific tasks even though they are not particularly

competent in English, we differ in the perspective on the relationship between language proficiency and academic achievement in science. The question therefore is whether it is language proficiency (alone) that provides the means for surmounting the obstacles to understanding science or whether there are other language analytical and text analytical skills. The study by Atebe & Schafer (2011) underscores this point by arguing that students' acquisition of the correct terminology in school geometry is also important for their success in the subject. To demonstrate this point, learners' understanding of thirty (30) terms describing cycles, triangles and quadrilaterals and lines and angles in plane geometry was examined. Results of the analysis showed that learners had weak understanding of basic terminology associated with high school geometry. From the standpoint of other studies conducted in terminology, the scope of language proficiency would among others comprise knowledge of textual cohesion (Rogers2007); knowledge of grammatical relations or thematic patterns (Antia

& Kamai, 2006); ability to analyze collocations (Antia, 2002) and ability to identify perspectives in textual progression (Bowker, 1987).

2.11 Summary and conclusion of the chapter

This chapter reviewed current and relevant literature on lexical semantics, text-linguistics and terminology in order to clarify our understanding of terminology variation. The first part of the chapter described the three conceptual approaches to the study of lexical variation. The first approach discussed is the formal approach which emphasizes the semantics or logical properties of lexemes. The second is the textual-functional approach where the interest is on the cohesive harmony of words and the meaning potentials in pattern of lexis. The terminology approach, which is the third, explores the dynamics of terms is specialized text. The second part of the chapter discussed term variation from the perspective of textbooks and textualization or (writing

process) while the third attempted a critique of the view that language proficiency is a correlate of science achievement and highlights the neglect of the issue of processing terminology in research on language in education.

In the third section of the chapter, three research strands on understanding scientific/technical texts were examined. They include: (a) studies by language educationists who see the challenge of underachievement in the sciences as a matter of proficiency in the language of instruction (b) studies by terminologists who are interested in analyzing the lexical characteristics of scientific texts, and showing the implications for understanding science and (c) studies conducted from text-linguistics illustrating the importance of teaching of the different ways of saying or 'wording' the same science content.

Central to the review is the claim that, language proficiency as defined by language educationists is not a homogenous construct as claimed in a wide range of studies discussed. We further argued that, challenges which variant terminology could pose to learners are not simply or easily addressed by language proficiency. The literature review section is concluded by suggesting a broader view of language proficiency that includes language and text analytical skills based on insights from research conducted in terminology, text-linguistics. It is anticipated that a broader conception of language proficiency of this nature can be beneficial to learners in their effort to mitigate the negative effects of term variation in their engagement with written science. This view is also shared by Lemke (1990) even though he noted that the educational system has neglected the teaching of the different ways of saying or 'wording' the same science content.

CHAPTER THREE

THEORETICAL FRAMEWORK

3 Introduction

This chapter describes the theories underpinning the study and illustrates in parts how the theories can be used to examine the dynamics of terminology in Nigerian and South African Life Sciences textbooks for high school. The theoretical framework adopted for the study combines insights from terminology, systemic functional linguistics and legitimation code theory. From Terminology studies, the study adopted Gerzymisch-Arbogast's (1996 & 2008) context specific term model to describe the typology of term variants in Life Sciences textbooks. From a broadly Hallidayan systemic functional linguistics, transitivity analysis was used to model clauses with variant terms while thematic pattern analysis as developed by Lemke (1990) was used to illustrate how clauses with variant terms can activate the same meaning. Lastly, Maton's (2013) legitimation code theory from Sociology of Education was used to describe the pedagogic functions of term variation in Life Sciences textbooks. Sections 3.2 to 3.4 provide an overview of each theoretical orientation and the associated analytical tools for each of the framework adopted.

3.1 Gerzymisch-Arbogast's context specific term model

Contrary to the widespread view that scientific or technical text genres are different from non-specialized genres in the way words/terms are used, Gerzymisch-Arbogast (1996 & 2008) argues that the senses of terms and the terms for given senses as represented at a system level (e.g. in dictionaries and glossaries) sometimes differ from what one encounters at the parole level of specialist texts. She provides an account of the relationship between language systems

and language use as a means of framing variation in the meaning of terms in special-language texts. She further develops an elaborate conceptual apparatus to buttress these claim and refers to variations as contamination. Figure 1 presents an adapted and simplified form of Gerzymisch-Arbogast's original model cited in Antia et al (2005).
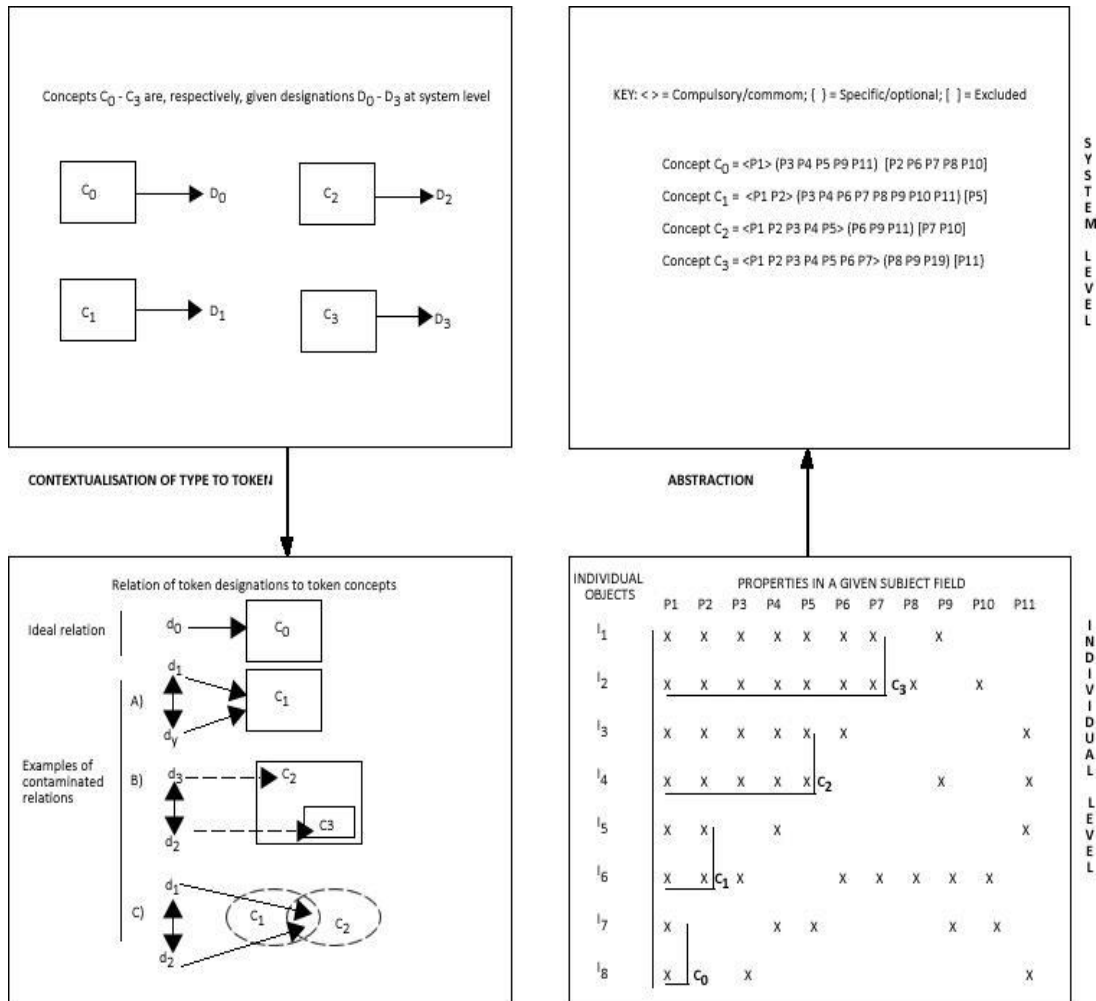
Figure 1: Adaptation of Gerzymisch-Arbogast's context-specific term model.

Figure 1 shows how concepts are formed and how established term-concept relations may not always be maintained – thus giving rise to term variation. As depicted in Figure 1, there are two levels: the individual level of objects in the real world with their properties, and the system level

of concepts. The individual level (the bottom right pane) has two columns corresponding to individual objects and the other for properties corresponding to these objects (as specified in a given field). On the basis of these object properties, concepts are formed at the system level via abstraction.

As further depicted at the system level (top right pane), concepts are seen as being made up of characteristics corresponding to object properties. Every such concept is made up of three types of characteristics/properties: compulsory to all instances of the concept; specific to some instances of the concept; not part of (i.e. excluded from) the concept. For concept O, for instance: P_1 as compulsory characteristic; P_3, P_4, P_5, P_9, P_{11} are specific while P_2, P_6, P_7, P_8, and P_{10} are excluded from all and any instances of Concept O. We see from the top left pane in Figure 1 also that at the system level, concept-term/designation assignments, that is, what a disciplinary convention says should be the designation of given concepts as these were previously defined at the system level are clearly specified. The bottom left pane on the other hand represents the individual level or the parole or text level – that is, realizations of the system assignment of concept-designation. We also see that the process of contextualization shows that at times system level specifications will be maintained (i.e. ideal relationship) as illustrated by example (a); at other times, the relationship will be contaminated as depicted by examples (b) and (c) in the lower left pane of the individual level.

Term contamination according to Gerzymisch-Arbogast(1996) manifests both at the level of designation or term and at the level of the concept. At the level of designation, term contamination of similarity results if two terms e.g. *CNS and Brain and spinal cord* are used

interchangeably so as to represent the same or similar concepts at system level. It also manifests at the level of designation as contamination of inclusion when two terms e.g. *Fossils,* a superordinate term, and *Marine Fossils*, a subordinate term, are used interchangeably so as to represent the other concept at system level. Contamination of intersection on the other hand manifests when two terms, e.g. *Bacteria and Microbes* are used interchangeably so as to represent intersecting concepts at system level. To avoid the use of the word contamination which can sound somewhat pejorative, the three categories of term contaminations identified in the context specific model will henceforth be referred to as Type 1 variation (contamination of similarity), Type 2 variation (contamination of inclusion) and Type 3 variation (contamination of intersection).

There are other frameworks that have been put forward by variationist scholars in previous research (e.g. Bowker, 1987; Jacquemin & Royaut´e, 1994; Dialle, 1996 & 2005). The context specific term model is preferred because it provides a broader framework for construing term variation. For instance, the scope of Type 1 variation combines graphical & orthographical variants; inflectional variants and morpho-syntactic variants. These categories were treated were all distinct typologies in Dialle (1996 & 2005). Type 1 variation can also be indexed by stylistic variants, pragmatic or register variants, dialectical, diachronic variants, domain or concept variants and explicative variants as described in Bowker & Hawkins (2006). The typological categories described in Fernandez et al (2002) can also be mapped on to Type 1 variation with the exception of lexical change which in our classification exemplifies Type 2 variation or contamination of inclusion. The other categories identified by Fernandez et al

(2002) comprise denominative variants, artificial forms of a term, acronyms, spelling changes and reduction.

Type 3 variation (contamination of intersection) appears to be an entirely a new construal of term variation. It results when two terms e.g. *inflammatory and erosive disease* and *inflammatory joint disease* are used interchangeably to mean the same thing. Here, the latter fails to activate the other characteristics of *inflammatory and erosive disease*, which describes a situation such as the inflammatory lesions in the mucous lining of the stomach (See. Elta, et. al, 1987). This typology cannot be subsumed under the category proposed in Dialle (1996 & 2005) neither does it neatly fit into the typology proposed by Fernandez et al (2002). It however shares some semblance with near synonymy in cognitive linguistics when it is interpreted as continuous or intermittent variation in the example of *seep* and *drip*. This is also because, *drip* is an intermittent event while *seep* is the continuous flow or leakage of a liquid (Edmond & Hirst, 2002).

As a prelude to more detailed exemplifications of the various types of term contamination, I shall illustrate inclusion by using an example from Lemke (1990) whose work will be discussed momentarily. On the first day of a Geography lesson, a teacher speaks of *marine fossils.* On the second day, while revising material of the previous day, the teacher speaks of *fossils.* Since marine fossils are a type of fossil, we can say that a hyperonym and a hyponym are being used interchangeably to refer to the same concept. The relation of contamination is represented in Figure 2 as reproduced from Antia (2002).
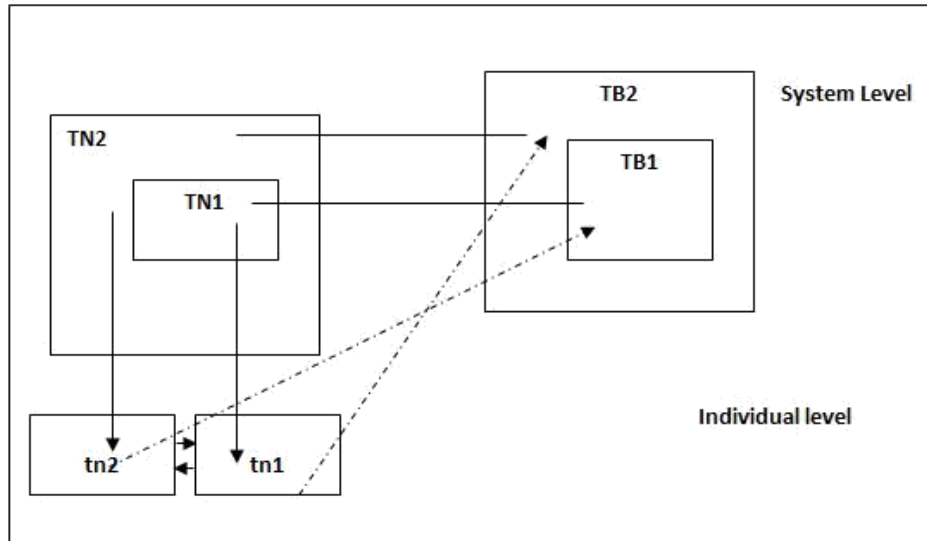
Figure 2: Example of contamination of inclusion cited from Antia (2002).

In Figure 2, at the system level, we have the ideal relationship where term TN1 (marine fossils) refers to concept TB1 (MARINE FOSSILS), and term TN2 (fossils) refers to concept TB2 (FOSSILS). The solid lines from TN2 to tn2 and TN1 to tn1 exemplify ideal contextualization. The broken lines from tn2 and tn1 to TB1 and TB2 respectively show contamination of inclusion where the term for a superordinate concept (fossil) is used for a subordinate concept (MARINE FOSSILS), etc. It can also be seen that tn2 and tn1 are used interchangeably to refer to the same thing. This and other forms of terminology variation identified earlier represent a major challenge that students face in learning the terms and concepts of written science.

For this study, the development of a typology of term variants in the corpus analyzed was motivated by the typological categories proposed in the context specific term model. The typological categories are also used to determine the significance of the language and science competences of learners in a test on processing variant terminology in Nigerian and South

African life sciences textbooks. Let us now consider the second component of the multi-theoretical framework adopted for the study.

3.2 Lemke's construct of thematic pattern

The second component of our theoretical framework is Lemke's construct of thematic pattern. Lemke (1990) describes a thematic pattern as the ways in which we are able to say the same thing differently. Consider the following questions: (a) What kind of wave is sound? (b) Sound is what type of wave motion? (c) Is sound a longitudinal wave type or a transverse wave? Despite the variations of terms used to refer to sound (*wave, wave motion, longitudinal wave, transverse wave*), the semantic relation activated or thematic pattern is the same (i.e. the same semantic relation of classification runs through all the formations).

A thematic pattern does not occur in isolation: it forms part of a thematic formation (i.e. what all texts that talk about the same topic in the same ways have in common). Thematic patterns are important because they give expression to the grammar and rhetorical forms used in the speaking and writing of science (Lemke, 1990). In other words, they can show how lexically dissimilar formations may mean the same thing.

The functions of thematic patterns are varied. First, students can use them to reason their way through test questions, and identify the 'science' content in any text or talk and use it to ''talk science''(Lemke, 1990: 1). In respect of the identification of the science content in text and talk, the knowledge of thematic patterns enables students to establish a hypothesis of relatedness between lexically dissimilar items.

Lemke's construct of thematic pattern is important to this study because it explains the difficulties learners have in performing tasks that involve identifying and resolving term variation. It also forms part of the bases for suggesting how terminology variation can be responded to. In the example analyzed below from Lemke (1990:87) (See Figure 3), a Geography teacher uses a set of terms on day one in which he introduces the subject of the lesson; on day two, while revising the previous day's material, he uses another set of terms.

LESSON 1 MARCH 19,

TEACHER: What happened was, more than likely is, the **CRUST** was *PUSHED UP* OK, and when we say the **CRUST** was *PUSHED UP* we say that **IT'S** *UPLIFTED*. And that's why we find these <u>MARINE</u> <u>FOSSILS</u> up on mountain tops

LEGEND

BOLD   = [A]

UNDERLINED   = [B]

ITALICS   = [C]

LESSON 2 MARCH 20,

TEACHER: I'd like to go on with what we were talking about. And we were talking about <u>FOSSILS</u> that are used as evidence, that the **EARTH'S CRUST** has been *MOVED*. Now what did we say about these <u>FOSSILS</u> how do they help us... know that the **EARTH'S CRUST** has been *MOVED?*

STUDENT: Like you will find <u>FISH FOSSILS</u> on top of a mountain you know that once there was water.. up there, 'n the **LAND** *MOVED* or something.

TEACHER: OK, and what else besides......

Figure 3: Transcript of a Geography lesson cited from Lemke (1990:87).

Looking at item [A] of the legend, we notice that it refers to an object, which is severally called *crust* (two times) on day 1, and *earth's crust* (two times) and *land* (once) on day 2. Interestingly, all these terms enter into the same thematic pattern: patient (CRUST, EARTH'S CRUST) – process (PUSHED UP, UPLIFTED, MOVED – deleted agent which could be (SOMETHING). In all these occurrences, these terms are the patient of passive constructions. Legend item [B]

is a process referred to as *pushed up* (twice) and *uplifted* (once) on day 1. On day 2, the process is called *move* (twice), *something* (once). In all these cases, the processes are consistently preceded by the patient of a passive sentence. Legend item [C] is an object called by the teacher on day 1 *marine fossils* (once) and on day 2 it is called *fossils* (once) and a student calls it *fish fossils* (once). Each of these terms co-occurs with epistemic or evidential propositions: "And that's why we find these marine fossils up on mountain top"; "we were talking about fossils that are used as evidence, that the earth's crust has been moved"; "now what did we say about these fossils? How do they help us know that the earth's crust has been moved" and "like you will find fish fossils on top of a mountain you know that once there was water"(Lemke, 1990: 89).

Lemke suggests that a student who understands both lessons should be able to draw the following inferences:

- Crust, earth's crust, land and it refer to the same entity. Crust is a clipped form of earth's crust, land is a synonym of crust and it is co- referential with crust.

- There is a process that acts on the crust, earth's crust or land to cause an elevation.

- A fossil is a superordinate term while marine fossils and fish fossils are subordinate terms but are used interchangeably.

Conversely, a student who is unable to draw these inferences is unlikely to have understood both lessons.

Lemke outlines five semantic relations that can be used for thematic pattern analysis. They include nominal relations, which relate to qualities, quantities and types; taxonomic relations,

which relate one item to another in terms of synonymy, antonymy or hyponymy; transitivity relations, which specify relations between entities in terms of Process, Agent, Goal, Target, Beneficiary, Range, Medium; circumstantial relations, which indicate relations of an item to its location, time, manner, reason, materials, means; and logical relations, which show relations that tend to occur between a whole set of linked items: cause/effect, evidence/conclusion, generalizations/instance (Lemke, 1990). Lemke's framework is important to this study because it can explain the difficulties learners have in performing tasks that involve identifying and resolving terminology variation. It also formed part of the basis for suggesting how terminology variation can be responded to. Section 3.4 describes Maton's legitimation code theory and its relevance to the study.

3.3 Maton's legitimation code theory

The third component of the theoretical framework is legitimation code theory (hereafter LCT) from sociology of education, propounded by Karl Maton. The theory builds on Basil Bernstein's theory of language codes and discourse types and also extends Pierre Bourdieu's idea on field practice, by which is meant "a configuration of positions comprising agents struggling over status and resources to maximise their position" (Morton, 2006: 689). Maton describes LCT as a "multi-dimensional conceptual toolkit… for analysing the organizing principles (or legitimation codes) underlying practices" (Maton, 2013: p. 12). LCT also incorporates critical realism which claims that "reality should be understood as a stratified system of objects with causal powers" (Morton, 2007: 599). In other words, what we see as reality or observable experiences is a product of events and processes by hidden forces. LCT is therefore committed to probing beneath the surface of what is represented in discourses to understand reality in different contexts (Clarence, 2014; Maton, 2014; Martin & Yaegan, 2016).

Legitimation code theory is motivated by the prevalent "knowledge blindness" in educational research, where knowledge is seen as either something that resides in the mind of learners (also mental process) or as social power, (i.e. somebody's perspective) (Maton, 2013). LCT therefore advocates a paradigm shift from these perspectives of knowledge to a view that construes knowledge as "an object of study emergent from but irreducible to how individuals know" (Maton,2013:9). LCT is therefore committed to addressing this gap by foregrounding knowledge as an entity with hidden structures and properties which are yet to be determined exhaustively in education research and beyond. Consequently, LCT proposes a range of analytical toolkits for accounting for the organizing principles or knowledge codes to this effect.

LCT further draws on Bernstein's notion of discourses types to theorize on best practices that foster cumulative learning as opposed to segmented learning which lacks the capacity to empower learners to actively participate in a discourse community over time (Arbee, 2014; Jackson,2014). Bernstein (2000) distinguishes between horizontal discourse which is exemplified by subjects in the humanities (e.g. History, Literature, Economics) and vertical discourse or subjects in the natural sciences (e.g. Physics, Chemistry, Biology and Geography) (Bernstein, 2000). Vertical discourse is conceived as "organised knowledge systems with clearly principled knowledge, coherently structured and systematically integrated" while horizontal knowledge structures "consist of numerous specialised languages, each with specific criteria for specialised modes of analysis" (Jackson, 2014: 137). In other words, vertical discourses encode knowledge as distinct elements that have been built into a whole unit, while horizontal discourse encodes knowledge as varied elements with distinctive meaning.

LCT is also premised on the notion of depth ontology in critical realism which claims that "there are real, generative mechanisms and structures underlying events independent of human phenomenal experience." (Davis, 2011: 1; Bhaskar,1998a). In other words, reality is a product of hidden forces inconceivable to the human mind. It is therefore hypothesized in Legitimation Code Theory that beneath the surface of what is represented in discourses lies organizing principles or codes that need to be probed. The theory is therefore committed to unearthing these positions and dormant meaning tendencies together with their organizing principles using a multi-dimensional toolkit ranging from Specialization, Autonomy, Density, Temporality and Semantics. Each of the five dimensions of the theory provides lenses for examining the organizing principles or codes underlying practice in subject fields.

In this study however, the aim is to apply analytical tools from the semantic dimension of the theory to examine the pedagogic functions of term variation in life sciences textbooks. Legitimation code theory views field of practice as semantic structures and utilizes two codes namely: semantic density (SD) and semantic gravity (SG) as toolkits for examining the organizing principles that underpin practice in subject fields. Semantic density refers to "the degree of condensation of meaning within socio-cultural practices, whether these comprise symbols, terms, concepts, phrases, expressions, gestures, clothing while semantic gravity refers to the degree to which meaning relates to its context'' (Maton, 2013: 11).

Figure 4 (below) operationalizes the meaning of the two semantic codes using the specialized term H_2O and the less specialized term *water* as examples. Terms or concepts located within the upper right quadrant on the Cartesian map, e.g. H_2O, encode meaning that is abstract and

decontextualized (i.e.SD+) while terms that are located within the lower left quadrant of the map, e.g. *water*, encode meaning that is contextualized and easy to grasp (i.e.SD-). The operation of both codes as seen from Figure 4 is suggestive of a relation of entailment which means that, a term with meaning that is abstract (SD+) also encodes meaning that is decontextualized (SG-) and vice versa.
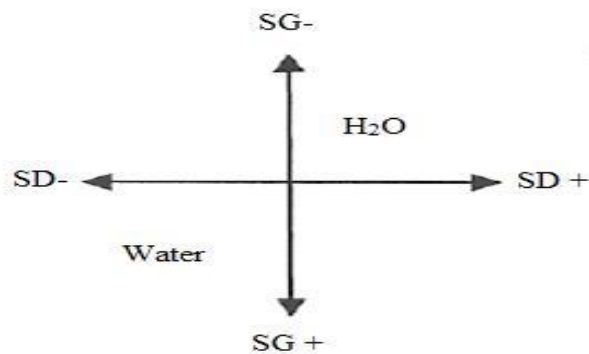
Figure 4: A Semantic plane indicating strengths of two semantic codes.

The semantic density (SD) and semantic gravity (SG) codes are important tools for creating different semantic profiles. A semantic profile indicates how the strengths of semantic gravity and semantic density vary or are maintained over time. Maton (2013) identifies five types of semantic profiles: high semantic flatline, low semantic flatline, downwards escalator, upwards escalator and a semantic wave. Figure 5 presents a graphical illustration of the four types of semantic profiles proposed in Maton (2013:17).
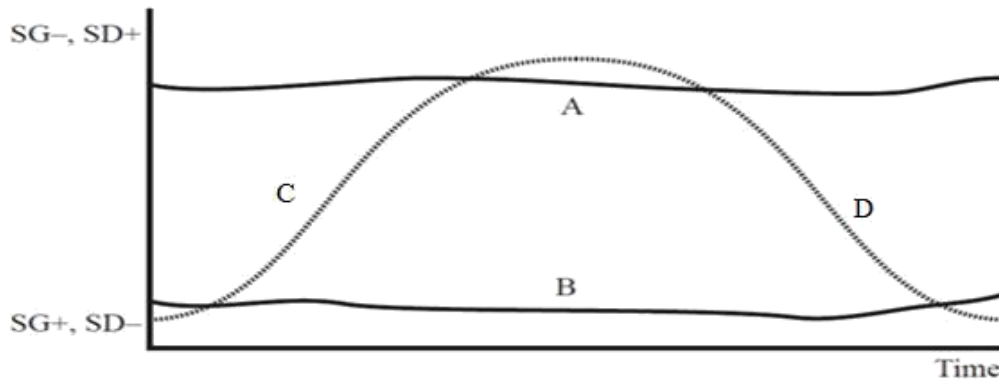
Figure 5: Typology of semantic profiles cited in Maton (2016: 17).

As Figure 5 shows, letter (A) symbolizes a profile described as 'high semantic flatline' while (B) denotes a profile called 'low semantic flatline'. By high semantic flatline we mean the static utilization of abstract and decontextualized meaning (SD+/SG-) over time while a low semantic flatline is the successive use of less abstract and decontextualized meanings (SD-/SG+) over time. A semantic profile denoting upwards escalator – also upshifting (Maton, 2014; Shey & Steyn, 2015) – is represented by (C) while a downwards escalator – also downshifting (Maton, 2014; Shey & Steyn, 2015) is depicted by letter (D). The former suggests an upward movement from meaning that is less abstract and decontextualized (SG+/SD-) to a meaning that is abstract and decontextualized meaning (SG-/SD+). The latter indicates a downward movement from an abstract and decontextualized meaning (SG-/SD+) to a meaning that is less abstract and decontextualized (SG+/SD-). A combination of profiles denoted with letters (C) and (D) on the other hand illustrate a profile called a semantic wave.

A semantic wave refers to the "recurrent shifts in context-dependence and condensation of meaning over time" (Maton, 2014:12). In a textbook context, this would mean the blending or weaving together of specialist and non-specialist terms when defining or describing a scientific

reality or process. We might illustrate what a semantic wave entails by citing an example from Maton & Martin (2013). On the first day of a Biology class on biological lines of defence, a teacher uses the abstract term *cilia* as an example of a biological mechanism against microbes that might enter the nostril (Ho et al, 2001). In the course of the lesson, the teacher unpacks the meaning of cilia by using a less abstract term with a grounded meaning called little hairs. Meanwhile, while concluding the lesson for the day, the teacher repacks or steps up the level of abstraction from the use of a word with low semantic density (little hairs SD-) to the use of a word with high semantic density (cilia SD+). Figure 6 depicts a semantic wave in a teacher talk on biological line of defence.
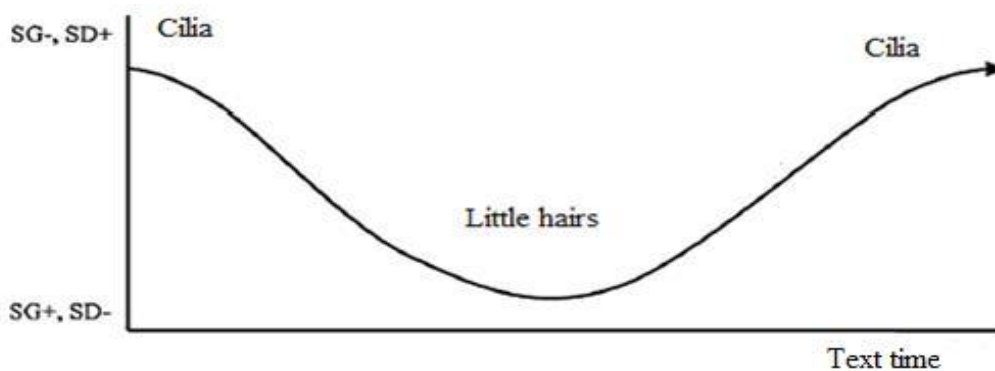
Figure 6: Semantic wave in a teacher talk on biological line of defence.

This shift from the use of a non-technical term to a more technical term in the course of the lesson according to Maton is the "key characteristics of knowledge-building and achievement" (Maton, 2014c: 181). For this study, LCT semantic provided a robust theory for explaining the nature of pedagogic variation in life sciences textbooks. It particularly was useful in determining whether texts exemplify instances of: semantic flatlines, consistently downwards or upwards

escalator or a semantic wave. Furthermore, semantic density (SD) and semantic gravity (SG) codes, provide a meta-language for categorizing terms and their variants according to their levels of abstractions. The emphasis in this study was however on the description of the nature of pedagogic discourse based on the semantic density code.

3.4   Summary of the chapter

It would be recalled that a multi-theoretical framework was adopted to examine the dynamics of terminology in Nigerian and South African life sciences textbooks. This chapter provides an overview of the theoretical framework adopted, their analytical categories and their relevance to the study. As stated from the outset, the frameworks adopted comprise Gerzymisch-Arbogast's context specific term model, Lemke's construct of thematic pattern and Maton's legitimation code theory. The chapter also describes how each component of the framework can be applied to achieve the relevant research objectives of the study. The adoption of a multi-theoretic framework was motivated by the need for a nuanced perspective on the pedagogic functions of variation in view of the opposing theoretical orientations on the phenomenon.

A further rationale for adopting a multi-theoretical framework is the need to conform to the specifications of the research design which specified the utilization of varied data sources and analytical paradigms. The next chapter examines the research methodology part of the study on the research design, sources of data required to answer the research questions, the study area, method of data analysis and interpretation and ethical aspects of the study.

CHAPTER FOUR

RESEARCH METHODOLOGY

4   Introduction

This chapter describes the methodology used in conducting the research and outlines the procedures that were followed to achieve the aim and objectives of the study. The chapter thus provides information on the research design, the sources of data and a description of the locations where the study was conducted. The chapter also gives an overview of the study sample, the criteria used in selecting participants for the study and how the test was conducted. The chapter ends with a description of how the data collected were analysed and the ethical regulations guiding the conduct of the study.

4.1   Research design

This study adopted a mixed-method research design in order to examine the dynamics and effects of term variation in high school life sciences textbooks. This design enabled us to use qualitative and quantitative approaches for relevant research objectives and to triangulate by using multiple analytical frameworks (Spratt et al, 2004; Creswell, 2008). A qualitative analytical method was used for objectives 1, 2 and 6 (as stated in Chapter One), while quantitative method was used to address objectives 3, 4 and 5.

4.2   Data type, sources and collection

The requisite data for the study were derived from the subject field of Life Sciences. The choice of life sciences was motivated by the researcher's familiarity with the subject. A further rationale is the pervasiveness of term variants in the subject field of life sciences. There were three sources of data.

The first source of data comprises a corpus of texts derived from six contemporary high school life sciences textbooks recommended for use in South Africa and Nigeria. Table 1 presents the selected Nigerian textbooks that were used for the study while Table 2 presents the South African textbooks.

Table 1: Selected Nigerian textbooks used for the study

Title	Authors	Publishers	Year	Grade
New Biology	Sarojini, et. al	African First Publishers	2013	12
College Biology	Idodo-Emeh	IUP Limited	2009	12
Essential Biology	M.C. Michael	Tonad Publishers Limited	2012	12

Table 2: Selected South African textbooks used for the study

Title	Authors	Publishers	Year	Grade
Understanding Life Science	T. Isaacs & S. Chetty.	Pulse Educational Services	2006	12
Focus Life Science	Clitheroe, et. al	Maskew Miller Longman	2011	12
Oxford Successful Life Science	Bezuidenhout, et. al	Cambridge University Press	2011	12

Passages on five topics from both the Nigerian and South African selected textbooks were then excerpted. The topics in the Nigerian textbooks include: nervous coordination, the cell, nutrition in plants, nitrogen cycle and respiration in plants. For the South African textbooks, the selected topics comprise nervous coordination, the cell, nitrogen cycle, blood circulation and transport system in plants.

For each of the topics selected, key themes (expected learning outcomes) were identified with the help of Biology teachers. For the topic on Nervous coordination for instance, examples of expected learning outcomes are (1) types of neurones (2) the functions of the different neurones (3) the structure of neurones. Then one or several such expected learning outcomes were chosen (e.g. the functions of different neurones). Thereafter, a number of clauses expressing this given expected learning outcome were identified from each textbook in order to determine what Lemke (1990) calls thematic formation, that is, the network of shared grammatical relations. Table 3 exemplifies clauses related to the functions of neurones in both Nigerian and South African life sciences textbooks.

Table 3: Selected clauses describing the functions of neurones

Text source	Clauses describing the functions of neurones
Text 1	Sensory(afferent) neurons transmit impulses from receptors to the CNS
Text 2	Sensory neurones carry impulses from stimulus receptors to the CNS
Text 3	Sensory 'afferent' neuron transmit impulses from sensory cells towards CNS (brain and spinal cord)
Text 4	Sensory neurons carry impulses from the receptors to the brain and spinal cord
Text 5	Sensory neurons transmit information from the receptors to the brain and spinal cord
Text 6	Neurons carry messages (electrical impulses) from one part of the body to Another

Once the clauses were identified from the Nigerian and South African textbooks, they were mapped on a Transitivity table to determine whether they have similar thematic patterns.

In selecting the topics, I was guided by the current Life Sciences syllabus and scheme of work recommended for use in Nigerian and South African high schools. The researcher also consulted teachers from the respective schools to determine the range of topics treated in the selected textbooks. This was necessary to ensure that the topics selected are those recommended for use in the curricula of both countries selected for the study. The topics selected had all been taught to learners at the time of the research. The second source of data was the performance scores of learners in a written task meant to ascertain their ability to cope with terminology variation. In this regard, learners in each country were given text excerpts on a topic from, say, textbooks 1 and 2, and relevant questions that used synonymous wording from, say, textbook 3. In the excerpt and the question, although the wordings were in part dissimilar, the thematic patterns were identical. The idea was to find out whether students can use that knowledge to establish a relationship between, for instance, a subordinate term (e.g. *nitrogenous compound*) in the test question and a superordinate term (e.g. *organic substances*) in the text excerpt**.** Textboxes 1 and 2 exemplify the test questions and reference text given to the learners.

Question 1: Nitrogen fixing bacteria converts nitrogen in the atmosphere to nitrogenous compounds. True OR False

Textbox 1: Sample test question

A few species of bacteria called the nitrogen fixing bacteria can synthesize organic substances like proteins, from atmospheric nitrogen. Some of these bacteria are free living in the soil. Others, like Rhizobium, live in root nodules

Textbox 2: Sample reference text

Textbox 1 shows the sources of wording for question 1, and allows us to compare this wording to terms used in the reference text participants actually read. Whereas the question and the text both use nitrogen bacteria, differences in wording can be seen in the following pairs: *convert* (question) vs. *synthesize* (text); *nitrogen in the atmosphere* (question) vs. *atmospheric nitrogen* (text); *nitrogenous compounds* (question) vs. *organic substances like proteins* (text).

The questions were developed by the researcher and verified by a Life Sciences teacher to ensure that the questions had content validity. After the test questions had been validated by teachers, a pilot study was conducted by the researcher to test logistics and the reliability of the

test questions. The test item had a Cronbach alpha reliability measure of (10 item test α = .70)

which is acceptable because it falls within (α=.5 -.9). The test was then administered to learners in both Nigeria and South Africa at different times Data obtained after the tests were administered were then used to answer the four research questions listed below as well as the three research hypotheses. The research questions are as follows:

(a) what types of variant terminology are to be found in the Nigerian and South African Life science textbooks?

(b) how widespread is variant terminology in Nigerian and South African life science textbooks?

(c) what is the significance of language proficiency to the achievement of learners in test on identifying and processing variant terminology?

(d) what is the significance of science competence to the achievement of learners in test on identifying and processing variant terminology?

(e) is there a significant difference in the performance of Nigerian and South African learners in test on identification and processing variant terminology in life sciences textbooks?

(f) how can observed patterns of cognitive processing of term variant be explained theoretically?

(g) what teaching and learning methods can be used to address any observed challenges posed by variant terminology in science textbooks?

The research hypotheses on the other hand are as follows:

H0$_1$: There will be no significant correlation between learners' English language proficiency and their performance in tasks on identifying and processing variant terminology in life sciences textbooks.

H0$_2$: There will be no significant relationship between learners' science competence and their performance in tasks on identifying and processing variant terminology in life sciences textbooks.

H0$_3$: There will be no significant difference between the performance of Nigerian and South African learners in tasks on identifying and processing variant terminology in life sciences textbooks.

The audio-recordings of learners' deliberation constituted the third source of data. As part of the design, a subset of the participants was required to work collaboratively in answering test

questions. In other words, while a group of learners answered the test questions independently in writing, a smaller group worked in groups, holding discussions. The participants were also told to verbalize their thoughts so they could be audio-recorded. These verbalisation or protocol data are used in educational research to identify and evaluate students' knowledge structures and cognitive processes while they are engaged in solving a problem, interpreting a chart, reading a passage, or completing an activity (Ercikan et. al, 2010). For the current study, they were required to determine the cognitive effects of terminology variation on learners' achievement in tasks on processing variant terminology. A voice recorder was then used to record five group discussion sessions per school in all four schools selected for the study. Each group comprised three discussants headed by a team leader who coordinated the discussion.

4.3   The study area

The study was conducted in Adamawa state, North Eastern Nigeria and in Cape Town in the Western Cape Province of South Africa. The choice of both study areas was motivated by the prevalence of underachievement in science in public schools and debate around the issue of whether language proficiency and home language instruction are correlates of achievement in science. In Nigeria, high schools comprised public schools, private schools and special science schools. All the school types run either arts or science curricula but there are some schools that run both curricula concurrently. The choice of school sample was guided by a policy document on the 6-3-3-4 system of education and data from the Planning and Statistics units of the Ministry of Education (NPE, 1994 & 2005; MoE, 2005).

The researcher also used statistics on the distribution of infrastructure and schooling conditions in Nigeria as documented in the National Bureau for Statistics and World Bank Reports. In

South Africa on the other hand, the National Quintile guided the choice of the schools in South Africa. Motivated by these policy documents, a special science school located in rural area and an elitist secondary school located in an urban area running both arts and science curricula concurrently were selected for the Nigerian experiment.

For the South African experiment, a Dinaledi or the special science school and a Special Arts school were selected. Dinaledi schools were set up to "contribute to the skills deficits that have been reported in the sectors of the economy requiring competence in mathematical and scientific skills" (DET, 2005).The schools are mostly patronised by learners of African descent, of whom most are from the townships. The language proficiency levels of learners from such backgrounds are weak and it is a common practice in such schools for teachers to use the home language for teaching and learning purposes. The Arts and Culture focused schools, on the other hand, offer subjects in the humanities (e.g. dance, drama, visual art, design and music). They also offer science subjects which are not compulsory (DET, 2005).

The TIMSS (2011) project indicated that learners attending schools in quintiles 1, 2 and 3 tend to be Black and to come from communities with a low socioeconomic status, while learners in schools in quintiles 4 and 5 tend to belong to higher socioeconomic levels and are typically White and Indian, but also Coloured and Black. Learners from Arts based schools are perceived to be strong in language and dramatic arts, while those from Science based schools are generally perceived as having a high competence in science. From the foregoing, the high school contexts in both Nigeria and South Africa have some similarities, as seen in the data from the Planning Research and Statistics Unit in Nigeria and the National Quintiles for schools in South Africa

(MoE, 2005; TIMSS, 2011). This means that the schools selected for the study have met the inclusion criteria because they have shared attributes.

4.4   Participants, sample and sampling procedures

Two hundred (200) learners from Nigeria and South Africa participated in the study. Thirty-five (35) learners from each school answered questions individually in the part of the test on identifying variant terminology in textbooks while fifteen learners, working in groups of five, were involved in the test set to determine the cognitive effects of variant terminology. This number falls within the range of 170 to 400 in comparable quantitative studies (Awofala, 2012; Ayodele, 2013; Fakeye, 2014).

- After school authorities and educators had been briefed and permission to conduct the research obtained, one hundred (100) Grade 12 learners in each country were recruited for the study. At each school, the participants were recruited based on the following criteria: Two school teachers of English language and life sciences in charge of learners' academic records across each stream were requested to identify a list of learners who were relatively strong and weak in English language and life sciences. These academic profiles were used to place learners into groups for assessment purposes. The performance of learners with these profiles was used to verify two hypotheses on whether the language and science profiles of learners were factors of achievement in the test administered.

- Based on the students' profile data supplied by both teachers, the researcher selected a random sample of fifteen (15) learners from within the predefined sample in each participating school. The remaining thirty-five (35) learners from the broader sample individually wrote a test involving identifying and resolving terminology variation. The

other 15 learners were assigned to five groups comprising three members each, where they worked collaboratively. The group membership consisted of learners with varying levels of English language proficiency and science performance profile. To address confounding variables, learners' academic dossiers for previous academic years were used to determine the competence of learners in English language and Science.

The selected learners were then grouped according to their strength in English and science in the ratio 1:2 or 2:1. The idea was to ensure that participants in each of the groups would be diverse in terms of their (teacher) reported strength in science and in English. Tables 4 and 5 present the sample size and the sampling technique adopted in selecting the Nigerian and South African learners.

Table 4: Sample size and sampling techniques for the study

Study Area	Level	Type of test and criteria for selecting participants	School A	School B
Nigeria	SSS3	1 Group Test: Dialogue Think-Aloud Protocol Test on identifying and resolving term variation Criterion for the Selection of participants: Purposive Sampling	15	15
		2. Individual Test: Test on identifying and resolving term variation Criterion for the selection of participants: Random Sampling	35	35

Table 5: Sample size and sampling techniques for the study

Study Area	Level	Type of test and criteria for selecting participants	School A	School B
South Africa	Grade 12	1.Group Test: Dialogue Think-Aloud Protocol Test on identifying and resolving term variation Criterion for the Selection of participants: Purposive Sampling	15	15
		2. Individual Test: Test on identifying and resolving term variation: Criterion for the selection of participants: Random Sampling. Total	35	35
			100	100

4.5   Administration of test

The researcher worked closely with relevant teachers in identifying class sessions where the test could be conducted without disruption to the curriculum. The test was administered to learners after class teachers and students had agreed that science practical sessions were the convenient time for the study to be conducted. The test conducted was made up of two tasks. The first task was conducted during a science class session and involved thirty-five (35) learners reading texts individually and answering questions on how to identify and resolve terminology variation. The duration of the test was between ten (10 and fifteen (15) minutes.

The second task, on the other hand, required fifteen (15) learners from each school to deliberate on ten questions in groups of three. This second task consisted of five sessions, each of which was expected to last forty-five (45) minutes. This task was not conducted in an "intact" classroom like the earlier individual test. It was rather conducted during either a science

practical session, break period or evening prep period. Each group discussion session lasted for about twenty-five (25) to thirty (30) minutes. All the venues used for the group test were quiet enough for students' deliberations to be audio-recorded.

4.6   Data analysis

Gerzymisch-Arbogast's (1996) model of term contamination in texts was the starting point for the data analysis. It was used to address the first objective of the study on the nature and use of term variants in Nigerian and South African life sciences textbooks. To address this objective, grammatical categories from Systemic Functional Linguistics (Halliday & Matthiessen, 2004; Eggins, 2005; Thompson, 2015) were used to model clauses in which variant terms occurred. The essence is to make it easy to identify variations in paradigmatic constituents of the identified clauses. Varying uses of terms observed were then documented and classified using Gerzymisch-Arbogast's typology of term contamination.

To achieve the second objective of the study on the distribution of term variants in Nigerian and South African life sciences textbooks, the variant terms previously assigned to Gerzymisch-Arbogast's categories were counted up to determine their statistical distribution within and across the Nigerian and South African textbooks. This finding was further used to determine what category of variation (contaminations of similarity, inclusion, intersection, etc.) in Gerzymisch-Arbogast's typology occurs most or least frequently across the constituents of the clauses analysed.

The next step of the analysis was the use of inferential statistical tools (Pearson Product-Moment Correlation Test and Chi-Square tests) to test three null hypotheses formulated based

on the third, fourth and fifth objectives of the study. To examine the third and fourth objectives

– on whether there was a statistically significant relationship between performance scores and

learners' profiles in English and science – the aggregate scores of the Nigerian and South

African learners who wrote the tests individually were first graded by the researcher and verified

by two Life Sciences teachers to ensure inter-rater reliability.

The scores of learners with different profiles were then analysed using the Pearson Product-

Moment Correlation Test (PPCT) test. The computed values were used to determine whether

or not the usage of term variants had significant effect on: a) students determined to be relatively

good in English language and those who are comparatively weak; and b) learners coded as

relatively strong in science and those comparatively weak in science.

On the fifth objective – which is set to determine if there was a statistically significant relationship

between performance scores of Nigerian and South African learners who wrote the test in groups –

we employed a chi-square statistical test suited for approximation of the goodness of fit between a

set of observed variables and those expected theoretically (Satorra & Bentler, 2001). To achieve

this, the aggregate scores of the Nigerian and South African learners who wrote the individual test

were first graded and verified by two Biology teachers to ensure inter-rater reliability. The scores

of Nigerian and South African learners who wrote the test in groups were analysed using the Exact

Fisher statistical test. Results from the analysis were then used to determine whether there was a

correlation between the performance of Nigerian and South African learners in tasks on processing

variant terminology

With respect to the sixth objective – to determine whether patterns of cognitive processing of term variants by learners can be explained theoretically – I drew on Gerzymisch-Arbogast's (1996 & 2008) context-specific term model, Lemke's (1990) construct of thematic pattern and Legitimation Code Theory to analyse the dialogue Think Aloud Protocols of learners, (hereafter protocol data). The researcher related observed cognitive processing steps e.g., recognizing a problem, monitoring the problem and the solution eventually arrived at, (cf. Lörscher, 1991) to types of terminology variation and the extent to which thematic pattern analysis (cf. Lemke, 1990) was successfully drawn on or could have successfully been drawn on. Insights from legitimation code theory on the other hand were used to determine the knowledge type or semantic density of the term variants in each test question and how it fostered or impede learning.

To achieve the seventh objective – on the need to develop methods within the content area that address the issue of terminology variation in science textbooks – I proposed a content integrated terminology literacy that can serve as a framework for teaching and learning science in the high school. It was further illustrated how teachers can use the proposed framework to address peculiar challenges posed by term variation.

4.7   Ethical statements

The researcher ensured that ethical regulations guiding the conduct of research were strictly adhered to in the course of carrying out the study. Permissions were sought from both the management/educators and learners in the various schools where data were generated in both Nigeria and South Africa. Approval letters from the proprietors and principals of schools in Adamawa, North East Nigeria and the Western Cape Education Department are in the Appendix

section of the study. Learners were guaranteed of their right to privacy/anonymity and were given the choice to willingly withdraw from the study at any point. The researcher ensured that all participants were adequately informed of the research purpose, procedures, expected duration and the potential benefits. Consent forms were signed by all participating learners after the research aim and objectives were explained to them. A sampled learner consent form from each of the four schools, the ethical clearance approving the conduct of the study, and letters from the Western Cape Education Department and proprietors of schools in Nigeria are also included in the Appendix section of the study.

4.8   Summary of the chapter

This chapter describes the methodology adopted for the study and outlines the procedures that were followed to achieve the aim and objectives of the study. The next section of the study presents results on the typology and distribution of term variants in Nigerian and South African life sciences textbooks.

CHAPTER FIVE

TYPOLOGY AND DISTRIBUTION OF TERM VARIANTS IN NIGERIAN AND SOUTH AFRICAN LIFE SCIENCES TEXTBOOKS

5   Introduction

The previous chapter described the methodology of the study where an overview of the research design, the sources of data, the sampling technique, the method of data analysis and data interpretation were described. The chapter also outlined the ethical guidelines governing the conduct of the study. This chapter presents and discusses results relevant to objectives 1 and 2 of the study. As stated in chapter 1, the first objective is to develop a typology of term variants in Nigerian and South African life sciences textbooks while the second objective is to determine the statistical distributions of the typology of term variants identified within and across the Nigerian and South African life sciences textbooks.

Before presenting these results, we shall first present an overview of the nature and use of terminology in the aforementioned textbooks, based on the treatment of two topics. To achieve these objectives, a transitivity table specifying the grammatical class and functions of clauses was used to illustrate how term variation manifested in the various constituents of the analysed clauses. Each transitivity table contains a commentary section which further elaborates the typology of term variations of observed and described clause constituents. On the one hand, Table 6 presents results on the nature and use of terminology in selected passages on sensory neurones in three Nigerian textbooks. Table 7, on the other hand, describes the process of diffusion in selected passages from three South African textbooks. A comprehensive analysis of all the other topics can be found in the appendix..

Table 6: Term variants in selected clauses on sensory neurones in Nigerian life sciences textbooks

Function	Actor	Process:	Goal	Circumstances: Place		Typology of variation
		Material		**Place α (αlpha)**	**Place β (beta)**	**Actor:** Type 1 variation or contamination of similarity manifests intra-textually in *New Biology* and *Essential Biology*; Type 1 variation or contamination of similarity between the orthographic variant, *sensory neurones* and *sensory neurons* in *New Biology* and *Essential Biology*.
Class → Data sources	**Nominal group**	**Verb**	**Noun**			
New Biology	Sensory (afferent) neurones	transmit	impulses	from receptors	to the CNS	**Process:** Ideal relation in *New Biology and Essential Biology;* Type 1 variation or contamination of similarity involving *carry* and *transmit* in *College Biology, New Biology and Essential Biology*.
College Biology	Sensory neurones	carry	impulses	from stimulus receptors	to the CNS	**Goal:** Ideal relation manifests across the three text sources.
Essential Biology	Sensory (afferent) neurons	transmit	impulses	from sensory cells	towards the CNS (brain & spinal cord)	**Place alpha:** Type 1 variation or contamination of similarity manifests across the three text sources. **Place beta:** Ideal relation across the three text sources. Type 2 variation or contamination of inclusion manifests intra-textually in *Essential Biology.*

Reading Table 6 from the standpoint of Gerzymisch-Arbogast's (1996) context-specific term model, we see that, for the Actor slot, there is practically an ideal relation involving tokens of *sensory neurone*, the only variation for this token being of an orthographical nature – *neurone* and its variants *neuron* – which qualifies as contamination of similarity. The Nominal group in *New Biology* contains intra-textually the variants *sensory neurone* and *afferent neurone* which also exemplifies Type 1 variation or contamination of similarity. For the Process slot, ideal relation is also observed in *New Biology* and *Essential Biology* involving the consistent use of *transmit*.

There is, however, contamination of similarity between *carry* in *College Biology* and *transmit* in *New Biology* and *Essential Biology*. In the Goal slot, ideal relation involving the consistent use of *impulses* across the three text sources is evident. Conversely, contamination of similarity involving the use of the variants *receptors*, *stimulus receptors* and *sensory cells* is observed across the three text sources. Like the nominal group in the Goal position, ideal relation is noted in *New Biology* and *College Biology* involving *CNS*. It can also be seen that there is contamination of inclusion intra-textually in *Essential Biology* involving *CNS* and *Brain & Spinal cord.* Having described the typology and manifestations of term variants in the description of sensory neurones in three Nigerian textbooks, let us now consider the treatment of diffusion in three South African life sciences textbooks.

Table 7: Term variants in select passages on diffusion in South African life sciences textbooks

Function Class → Data sources ↓	Token Noun	Process: Material Verb	Goal Nominal group	Value: Place		Typology of variation
				Place alpha (origin)	**Place beta (destination)**	
Study and Master Life Sciences	Diffusion	is	movement of molecules of a substance (solid, liquid and gas)	from a region of high concentration	to a region of low concentration	**Token:** Exemplifies ideal relation across the three text sources. **Process:** Signifies ideal relation across the three text sources. **Goal:** Shows Type 2 variation or contamination of inclusion in *Study and Master Life Sciences*; Type 1 variation or contamination of similarity between *Oxford Successful Life Sciences* and *Focus Life Sciences*. **Place alpha:** Illustrates ideal relation involving the consistent use of the terms *area of high concentration* in *Study and Master Life Sciences* and *Focus Life Sciences*. There is also Type 1 variation or contamination of similarity involving the use of *area of high concentration* and *region of high concentration*.
Oxford Successful Life Sciences	Diffusion	is	movement of water particles	from an area of high concentration	to an area of low concentration	
Focus Life Sciences	Diffusion	is	movement of molecules	from a region of high concentration	to a region of low concentration	**Place beta:** Exemplifies ideal relation by the usage of the term *of low concentration*. Type 1 variation or contamination of similarity manifests in the use of *region of low concentration* and *area of low concentration*.

As depicted in Table 7, ideal relation is exemplified in the Token and Process slots by the consistent use of the term *diffusion* and the relational process verb *is* across the three text sources. In the Goal slot, Type 1 variation (contamination of similarity) is exemplified involving the use of the doublet *movement of molecules of a substance (solid, liquid and gas)* in *Study and Master Life Sciences*; *movement of water particles* in *Oxford Successful Life Sciences* and movement of molecules in *Focus Life Sciences.* In the Place alpha (origin) constituent, ideal relation is observed in both *Study and Master Life Sciences* and *Focus Life Sciences* involving the consistent use of *region of low concentration*. It is, however, further referred to as *area of low concentration* in *Oxford Successful Life Sciences*. Contamination of similarity also manifests in the Place beta (destination) constituent involving the locative variants *region of higher concentration* in both *Study and Master Life Sciences* and *Focus Life Sciences*. The relationship between *region of high concentration* and *area of high concentration* can be processed as an example of Type 1 variation (contamination of similarity).

The results presented in Tables 6 and 7 describe the nature and use of terms in life sciences textbooks in Nigeria and South Africa. Let us now consider the use of terms across these regions in order to underscore the pervasiveness of term variation in Nigerian and South African life sciences textbooks. Table 8 presents an overview of terminology variation in selected passages on osmosis across the Nigerian and South African life sciences textbooks.

Table 8: Term variants in selected passages on osmosis in Nigerian and South African life sciences textbooks

Function	Token	Process:		Value: Place		Typology of variation
		Relational	**Goal** Nominal group	**Place α (alpha)**	**Place β (beta)**	**Token:** There is ideal relation within and across the Nigerian
Class	Noun					and South African textbooks in the Token slot.
		Verb				**Process:** For the Process slot, ideal relation is exemplified involving the consistent use of the relational process verb *is*
Data sources						across the Nigerian and South African life sciences textbooks.
						Goal: There is ideal relation in *Essential Biology* and *Study and*
New Biology	Osmosis	is	passage of molecules of solvent	from a low concentrated solution	to a more concentrated solution	*Master Life Sciences* involving the use of *flow of water molecules.* Type 1 variation (contamination of similarity) is however exemplified across the Nigerian and South African
College Biology	Osmosis	is	diffusion of water molecules	from a region of low osmotic pressure	to a region of high osmotic pressure	textbooks involving the use of *passage of molecules of solvent* in *New Biology*; *diffusion of water molecules* in *College Biology; movement of water molecules* in *Oxford Successful Life Sciences*
Essential Biology	Osmosis	is	flow of water molecules	from a region of diluted or weaker solution	to a region of high concentration	and the doublet *movement(diffusion) of particles* in *Focus Life Sciences.*
Study and Master Life Sciences	Osmosis	is	flow of water molecules	from a region of low concentration	to a region of high concentration	**Place alpha:** Exemplifies Type 1 variation (contamination of similarity) across Nigerian and South African textbooks. **Place beta:** Illustrates Type 1 variation (contamination of similarity) within and across Nigerian and South African textbooks.
Oxford Successful Life Sciences	Osmosis	is	movement of water molecules	from an area of low water potential	to an area of high water potential	
Focus Life Sciences	Osmosis	is	movement (diffusion) of particles	from low concentration of water molecules	to high concentration of water molecules	

With respect to the nature of (contaminated) term usage, we notice from Table 7 that for the Token slot, there is ideal relation in the consistent use of *osmosis* within and across all six text sources. For the Process slot, ideal relation is exemplified involving the consistent use of the relational process verb *is* across the Nigerian and South African life sciences textbooks. For the Goal slot, at the level of term or designation, there is ideal relation involving the use of *flow of water molecules* in *College Biology* and *Essential Biology.* However, Type 1 variation is exemplified involving the use of *passage of molecules of solvent* in *New Biology; diffusion of water molecules* in *College Biology*; *movement of water molecules* in *Study Master Life Sciences* and the doublet *movement(diffusion) of particles* in *Focus Life Sciences.*

For Place alpha in the Value constituent, Type 1 variation (contamination of similarity) is exemplified across the three Nigerian textbooks involving *low concentrated solution* in *New Biology; low osmotic pressure* in *College Biology* and the disjunctive variant *diluted or weak solution* in *Essential Biology*. Type 1 variation (contamination of similarity) also manifests in the South African textbooks involving the usage of the terms *region of high concentration* in *Study and Master Life Sciences; area of high water potential* in *Oxford Successful Life Sciences* and *high concentration of water molecules* in *Focus Life Sciences*.

Term variation can also be observed in the Place beta slot of the Nigerian science textbooks. It manifests as Type 1 variation (contamination of similarity) involving the usage of *more concentrated solution* in *New Biology*; *high osmotic pressure* in *College Biology* and *high concentration* in *Essential Biology*. The pervasiveness of term variants noted in the Place beta slot of the Nigerian science textbooks is also observed in the South African textbooks. Term variation

manifests across the three text sources involving the use of *region of low concentration* in *Study and Master Life Sciences*; *area of low water potential* in *Oxford Successful Life Sciences* and *low concentration of water molecules* in *Focus Life Sciences*. From the standpoint of Gerzymisch-Arbogast's analytical categories, the use of terms in all these text sources exemplify Type 1 variation or contamination of similarity.

The results presented and discussed in Tables 6, 7 and 8 illustrate the fact that term variation is pervasive in Nigerian and South African life sciences textbooks for high school. It underscores the fact that the phenomenon is also widespread in the constituents of the clauses analysed. As a prelude to presenting the results on the typology and distribution of term variants in the data analysed, we first present an overview of ideal and contaminated relations observed in the data. Table 9 presents a summary of term variants (i.e. contaminated relation) and invariant terms (i.e. ideal relation) observed in the data.

Table 9: Overview of variant and invariant terms in Nigerian and South African life sciences textbooks

Clause Constituent	Nigerian corpus		South African corpus	
	Invariant terms	**Variant terms**	**Invariant terms**	**Variant terms**
Participant	(17)(47)	(16)(41)	(13)(34)	(16)(42)
Process	(08) (22)	(03)(08)	(07)(18)	(09)(34)
Circumstances	(11) (31)	(20)(51)	(18)(48)	(13)(34)
Total	(36)(100)	(39)(100)	(38)(100)	(38)(100)

Using the Participant clause constituent as an example, the convention for reading Table 9 is as follows: the figures under the invariant entries signify the frequency and percentage of occurrence of invariant and variant terms in the specified clause constituent. We see from Table 9 that the frequency of variant terms in the Nigerian corpus is greater (39) than the frequency of invariant terms, which has a frequency of thirty-six (36). In the South African corpus, the proportion of variant and invariant terms is equal (38). It should be noted, however, that the distribution of variant and invariant terms in the constituents of the clauses analysed is disproportional. As Table 9 indicates, the Participant constituent in the Nigerian corpus has the highest frequency (17) followed by Circumstances slot which had a frequency of eleven (11). The lowest is the Process slot, with a frequency of eight (8). The constituent with the highest proportion of term variants in the Nigerian corpus is the Circumstances slot which had a frequency of twenty (20). It is followed by the Participant constituent with a frequency of sixteen (16). The Process slot had the lowest frequency, at three (3).

A similar quantitative tendency involving a disproportional manifestation of variant and invariant terms is also observed in the South African corpus. But unlike the Nigerian clauses where the Participant has the highest frequency, the constituent with the highest frequency of invariant terms in the South African corpus is the Circumstances slot, which has a frequency of eighteen (18). The Participant constituent is the next in rank with a frequency of thirteen (13) while the Process slot manifests the lowest frequency, with seven (7) instances. As in the case of the Nigerian corpus, the Process slot in the South African corpus also has the lowest frequency of nine (9) term variants; though it is quantitatively higher than that observed in the Nigerian corpus. Having described the

frequency of variant and invariant terms observed in the data set, we now present results on the typology of term variants in Nigerian and South African life sciences textbooks.

5.1 Typology and manifestations of term variants in Nigerian and South African life sciences textbooks: Research question 1

The previous section presented results on the prevalence of variant and invariant terms in the data set analysed in order to underscore the fact that specialized texts (meant for teaching and learning) are also prone to variation. It can be seen from Table 9 that term variation in the data set is presented from a broad perspective. In other words, a coarse-grained analytical description of the distinctiveness of the term variants is lacking. This section therefore takes the analysis of term variation to the next level by using Gerzymisch-Arbogast's (2008) context-specific term model to further categorise each of the term v3ariants identified in the Nigerian and South African corpora. Figures 7 to 9 present a graphic illustration of the typology of the term variants observed in the corpora analysed, based on Gerzymisch-Arbogast (2008), while an overview of the manifestations of the different typologies in the Nigerian and South African textbooks is presented in Table 9.

The first typology developed is Type 1 variation or contamination of similarity. This results when two designations or terms (d_1 and d_2) are used to describe a concept (C_1). The nature and frequency of Type 1 variation is illustrated in Figure 7.
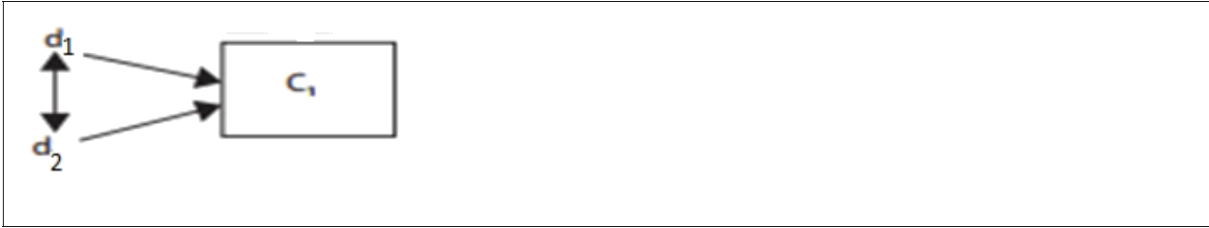
Figure 7: Graphic illustration of contamination of similarity or Type 1 variation.

The second typology is Type 2 variation or contamination of inclusion, which is a typology that results when a hyperonym or a superordinate term (d_3) and a hyponym or a subordinate term (d_2) are used interchangeably so as to represent the other concept ($d_3 = c_2$ or $d_2 = C_3$).
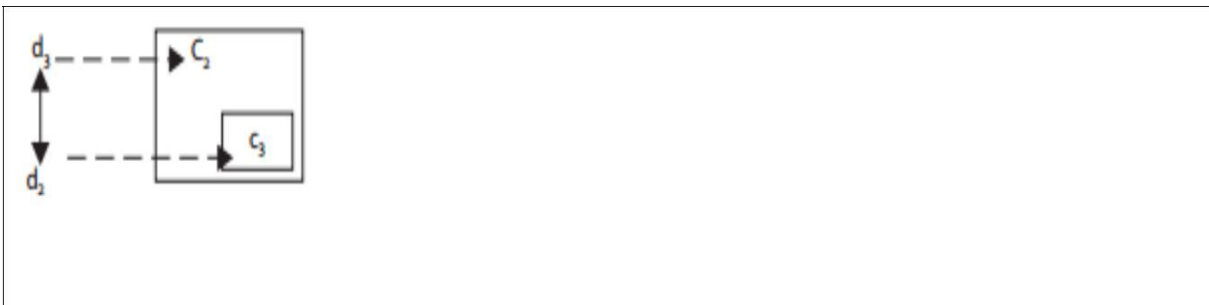
Figure 8: Graphic illustration of contamination of inclusion or Type 2 variation.

The third typology is Type 3 variation or contamination of intersection. It manifests when two terms (d_1 and d_2) are used interchangeably so as to represent concepts and are joined at the system level, as depicted at the point where the two arrows converge in Figure 9.

Figure 9: Figure 9: Graphic illustration of contamination of intersection or Type 3 variation.

The manifestation of the three typologies of term variation identified in the Nigerian and South African high school life sciences textbooks is presented in Table 10.

Table 10: Manifestations of term variants in Nigerian and South African life sciences textbooks

Typology of variation	Manifestations		
	Nigerian textbooks		South African textbooks
Type 1 variation	sensory neurons vs afferent		neurons nerve cells vs neurons
	impulses vs messages		transmit vs carry
	radiant energy vs sunlight		converts vs changes
Type 2 variation	central nervous system	vs	brain & spinal cord
	effector	vs	muscles and glands
Type 3 variation	denitrifying bacteria	vs	pseudomonas denitrificans
	ammonia	vs	ammonium compounds
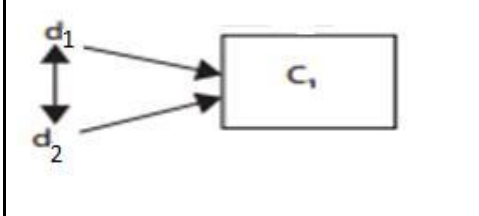
As Table 10 indicates, term variation manifests in both Nigerian and South African high school life sciences textbooks as Type 1 variation or contamination of similarity, Type 2 variation or

contamination of inclusion and Type 3 variation or contamination of intersection. We can see, however, that Table 10 indicates no quantitative tendencies of the three typologies of term variation identified in either the Nigerian or South African textbooks. Thus, the next section describes the distributions of term variation in these textbooks.

5.2 Distribution of the typology of term variants in Nigerian and South African life sciences textbooks: Research question 2a
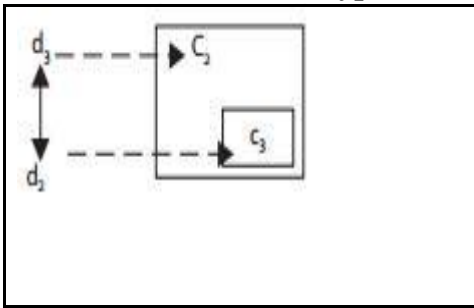
This section presents results on the quantitative tendency of Type 1 variation in Nigerian and South African life sciences textbooks. For each result to be presented, the nature of the typology as formulated in Gerzymisch-Arbogast (1996 & 2008) is graphically depicted alongside its frequency in the Nigerian and South African corpus. Table 10 presents results on the prevalence of Type 1 variation.

Table 11: Prevalence of Type 1 variation in Nigerian and South African corpora

	Frequency of Type 1 variation	Corpus
d_1 d_2 C_1	(30)	Nigeria
	(31)	South Africa
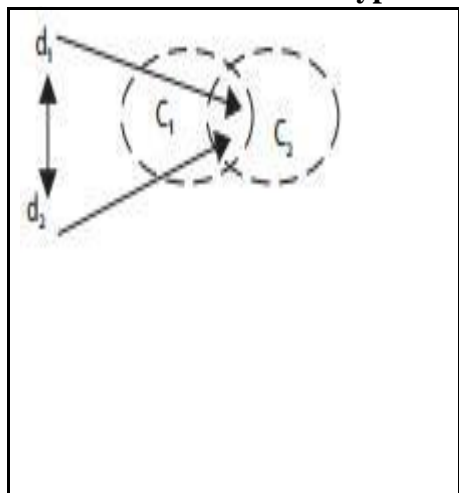
We see from Table 11 that Type 1 variation manifests more in the South African textbooks with a frequency of thirty-one (31), compared to the Nigerian textbooks, which manifest a frequency of thirty (30). Table 12 presents results on the frequency of Type 2 variation in the Nigerian and South African life sciences textbooks.

Table 12: Prevalence of Type 2 variation in Nigerian and South African corpora

	Frequency of Type 2 variation	Corpus
	(5)	Nigeria
	(4)	South Africa

As can be seen from Table 12, there is less total frequency of Type 2 variation than Type 1 variation in both the Nigerian and the South African corpora although the frequency of five (5) in the Nigerian corpus is higher than that found in the South African corpus (4). Table 13 presents the different frequencies of Type 3 variation in Nigerian and South African life sciences textbooks.

Table 13: Prevalence of Type 3 variation in Nigerian and South African corpora

	Frequency of Type 3 variation	Corpus
	(3)	Nigeria
	(3)	South Africa

Compared to the two typologies described earlier, it can be seen from Table 13 that Type 3 variation has the least frequency in both Nigerian and South African corpora, with a prevalence rate of three (3). Table 14 presents a summary of the quantitative tendency of the three typologies of term variants identified in the textbooks.

Table 14: Typology and distribution of term variants in Nigerian and South African life sciences textbooks

Typology of variation	Nigerian corpus	South African corpus
Type 1 variation	(30)(77)	(31)(80)
Type 2 variation	(05)(12)	(04)(11)
Type 3 variation	(03)(11)	(03)(09)
Total	(38)(100)	(38)(100)
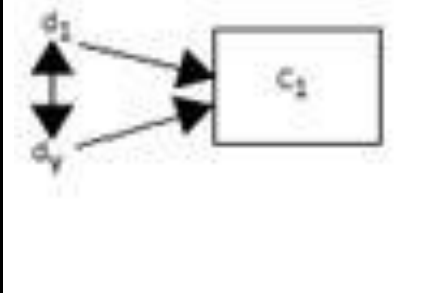
The convention for reading Table 14 is as follows: the figures under the entries Nigerian and South African corpora symbolize the frequency and percentage of occurrence of the typology of variation in respective corpus. Reading Table 14 from this standpoint shows that, out of the total variants identified in the Nigerian corpus, Type 1 variation comprises seventy-seven percent (77%), which is the highest frequency of occurrence. This variation type is followed by Type 2 variation, which is twelve percent (12%). Type 3 variation is the least frequent in the Nigerian corpus, at eleven percent (11%). Type 1 variation is also the highest in the South African corpus, at eighty percent (80%). Type 2 variation is the next in rank with a percentage of eleven (11%). Like in the Nigerian corpus, Type 3 has the least percentage of nine (9%). Let us now consider the distribution of term variants in the clause constituents of Nigerian and South African life sciences textbooks.

5.3 Distribution of the typology of term variants in clause constituents of Nigerian and South African life sciences textbooks: Research question 2b

This section presents results on the second objective of the study which is to determine whether the distribution of the three typologies of term variants identified (i.e. Type 1, 2 and 3) is evenly spread in clause constituents of Nigerian and South African life sciences textbooks. It can be noted that in the preceding section the results fail to account for the distribution of term variants at the clausal level of analysis. In order to address this, Table 15 presents results on the prevalence of Type 1 variation in the clause constituents of Nigerian and South African textbooks. Readers more
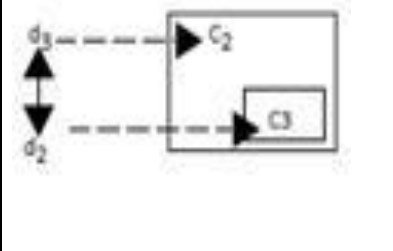
interested in the overall results may skip Tables 14, 15, 16 and go to table 17 which presents the

frequency of variants for all clause constituents.

Table 15: Frequency distribution of Type 1 variation in clause constituents of Nigerian and South African life sciences textbooks

	Participants	Process	Circumstances	Corpus
	(14)(46.6)	(03)(10)	(13)(43.3)	Nigeria
	(12)(38.7)	(09)(29)	(10)(32.2)	South Africa
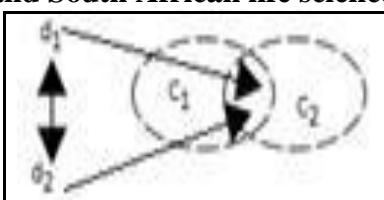
As we can see in Table 15, both Nigerian and South African corpora have a high frequency of Type 1

variation in the Participants slot, with fourteen (14) in the Nigerian corpus and twelve (12) in the South

African corpus. The next highest is the Circumstance slot, with a frequency of thirteen

(13) in the Nigerian corpus and ten (10) in the South African corpus. The process slot has the least

frequency of three (3) in the Nigerian corpus and (9) in the South African corpus. Table 16 presents

results on the prevalence of Type 2 variation in the clause constituents of Nigerian and South

African textbooks.

Table 16: Frequency distribution of Type 2 variation in clause constituents of Nigerian and South African life sciences textbooks

	Participants	Process	Circumstances	Corpus
	(1)(25)	(0)(0)	(4)(75)	Nigeria
	(1)(33)	(0)(0)	(3)(67)	South Africa

Unlike the distributional pattern observed on the manifestations of Type 1 variation, Type 2 variation manifests more instances in the Circumstances slot with four (4) occurrences in the Nigerian corpus and three (3) in the South African corpus. The Participants slot showed only one (1) occurrence in each corpus. There was, however, no instance of Type 1 variation in either the Nigerian or the South African corpora. Table 17 presents an overview of the distribution of Type 3 variation in clause constituents of Nigerian and South African life sciences textbooks.

Table 17: : Frequency distribution of Type 3 variation in clause constituents of Nigerian and South African life sciences textbooks

	Participants	Process	Circumstances	Corpus
	(1)(33.3)	(0)(0)	(3)(66.7)	Nigeria
	(3)(100)	(0)(0)	(0)(0)	South Africa

As depicted in Table 17 the Participants slot had the highest occurrence of Type 3 variation with one (1) instance in the Nigerian corpus and three (3) instances in the South African corpus. This is followed by the Circumstances slot, in which three (3) instances are recorded in the Nigerian corpus. The South African corpus recorded no manifestation of Type 3 variation in either the Circumstances or the Process slots. Type 3 variation for the Process slot was also not observed in the Nigerian corpus. Table 18 presents a summary of the distribution of term variants in the clause constituents of Nigerian and South African life sciences textbooks.

Table 18: Distribution of term variants in the clause constituents of Nigerian and South African life sciences textbooks

Clause constituent	Nigerian corpus(%)	South African corpus(%)	Total(%)
Participant	(16)(41)	(16)(42)	(32)(42)
Process	(03)(8)	(09)(24)	(12)(16)
Circumstances	(20)(51)	(13)(34)	(33)(42)
Total	(39)(100)	(38)(100)	(77)(100)

It can also be seen from Table 18 that the frequency of term variants in the clause constituents of Nigerian and South African life sciences textbooks is not evenly spread. In the Nigerian corpus, the Circumstances slot had the highest frequency of term variants with twenty (20; 51%) instances. The next was the Participant slot with sixteen (16;41%) occurrences while the Process slot had the least frequency, with only three (3;8%) occurrences. We also see in Table 18 that while the Circumstances slot in the Nigerian corpus had the highest frequency twenty (20), the Participant slot in the South African corpus that had the highest frequency with sixteen (16;42%) instances, followed by the Circumstances slot which had thirteen (13;34%) occurrences. As in the case of the Nigerian corpus, the Process slot recorded the least frequency, with nine (9;24%) instances.

Despite the uniqueness of the approach adopted, which describes the dynamics of terminology in the clause constituents as opposed to the practice where the frequency of term variants is estimated based on whole text or pages, a perspective from the semantic dimension of legitimation code theory might view our perspective as being logo-centric (personal communication with Jim Martin, April 4th 2015, Sydney). That is to say, the analytical approach gives more emphasis to the lexical component of language which in itself cannot exhaustively describe the reality of terminology in high school life sciences textbooks. This concern is also expressed in Kageura (2003) where it is argued that the extreme reliance on the meaning of individual terms and their prevalence in texts

cannot be said to be a true reflection of the dynamics of terminology in specialised texts. What this also means is that a full account of the dynamics of terminology would entail a description that accounts for how the lexical items interact with other words to form patterns of knowledge in textual progression. The application of this knowledge – lean approach to the analysis of the dynamics of terminology is the focus of the next section.

5.4   Distribution of knowledge units in the clause constituents of Nigerian and South African life sciences textbooks: Research question 2c

The first section of this chapter presented results on the quantitative tendencies of term variants in Nigerian and South African life sciences textbooks while the second section presented results pertaining to the distributions of term variants in clause constituents of these Nigerian and South African textbooks. This section, on the other hand, presents a qualitative analysis of the dynamics of term variation in Nigerian and South African life sciences textbooks, based on insights from the semantic dimension of legitimation code theory. The results presented are on the use of terms in describing the functions of neurones and diffusion in six high school life sciences textbooks. Likewise, the descriptions related to all the other topics can be found in Appendices 1 and 2.

Table 18 presents results on the manifestations of knowledge types and their semantic profiles (emergent properties) in Nigerian and South African high school textbooks on life sciences. Each table is followed by a simulation of the emergent patterns resulting from the interrelationship between terms used in describing the topics in three text sources. For ease of interpretation, each simulation is captioned as a figure which needs to be read concurrently with the relevant table preceding it. Table 19 presents a dynamic account of the flow of knowledge in the clauses of three

textbook accounts of the functions of sensory neurones with terms coded according to LCT semantics analytical categories.

Table 19: Typology of knowledge in three textbook accounts of the functions of sensory neurones

Function Class ➡ Data sources ⬇	Actor Noun	Process: Material Verb	Goal Noun	Circumstance: Place	
				Place alpha	**Place beta**
New Biology	sensory (afferent) neurons (SD-)	transmit (SD+)	impulses (SD+)	from receptors (SD+)	to the CNS (SD+)
College Biology	sensory neurons (SD+)	carry (SD-)	impulses (SD+)	from stimulus receptors(SD+)	to the CNS (SD+)
Essential Biology	sensory (afferent) neurons (SD-)	transmit (SD+)	impulses (SD+)	from sensory cells (SD+)	towards the CNS (SD+) (brain & spinal cord) (SD-)

In Table 19 the use of the generic term, *sensory neuron* in the Actor slot for *College Biology* has a relatively high semantic density (SD+). The specific doublet *sensory (afferent) neurons* in *New Biology and Essential Biology* on the other hand has a low semantic density (SD-) because of the added context given. The Material Process is realised by two different variants: *transmit* in *New Biology* and *Essential Biology*, and *carry* in *College Biology*. While the term *transmit* has a high semantic density (SD+) because of its high level of abstraction, the contextualised variant *carry* has a low semantic density.

The Goal, unlike the Material Process, is realised consistently by the semantically dense (SD+) term *impulses.* The Place alpha slot in the Circumstances component is also realised by three semantically dense variants (SD+) *receptors; stimulus receptors and sensory cells* across the three

text sources. The Place beta slot is consistently realised by a term that has a high level of abstraction (SD+) *CNS* in *New Biology and College Biology*. The contextualised *brain and spinal cord* in *Essential Biology* encodes a meaning that is semantically dense compared to *CNS*. Figure 10 models the flow of knowledge in the description of sensory neurons. For ease of interpretation, Text 1, Text 2 and Text 3 are used as substitutes for *New Biology*, *College Biology* and *Essential Biology* respectively.

Knowledge Type	Actor	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
SD+					
SD-					
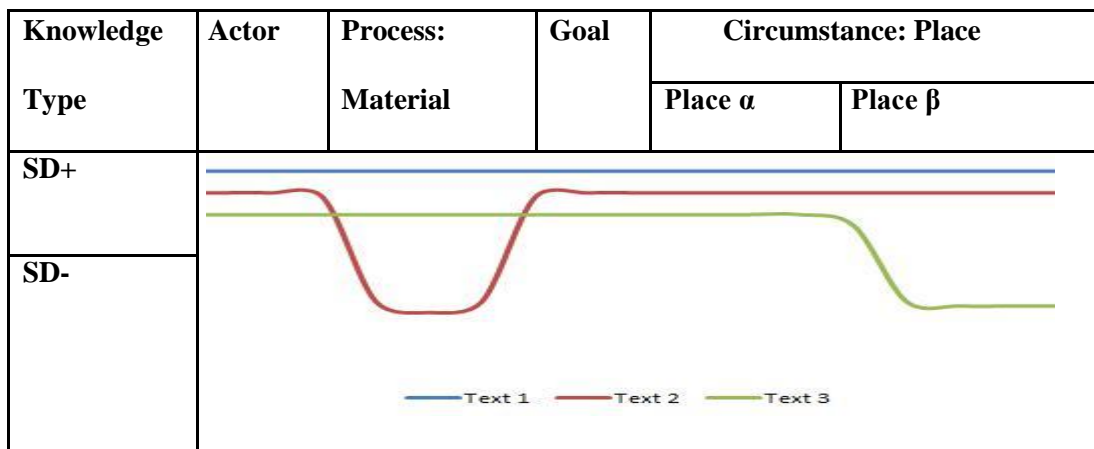
Figure 10: Flow of knowledge in three textbook accounts of the functions of sensory

We see from Figure 10 that the meaning encoded by the terms in the Actor, Process and the Circumstance slots in *New Biology* has a high level of abstraction (SD+) illustrating a profile known as a high semantic flatline (HSF) (See Text 1 in Figure 10). In *College Biology*, the meaning encoded in the Actor and Circumstance slots are both abstract (SD+) while that in the Process slot has a low level of abstraction (SD-) because it is contextualised or simplified. This pattern is called a semantic wave (SW) because the level of abstraction fluctuates from high to low as the text unfolds. Unlike the profiles depicted in Texts 1 and 2, Text 3, *Essential Biology*, illustrates a semantic profile called a downward escalator (DE). This is because of the shift from a dense or technical (SD+) meaning in the Actor, Process and Goal slots to one that is less dense or

contextualised in the Circumstance slot. Let us turn to the description of the types of knowledge

units used in describing diffusion and the emergent patterns that evolved from the three textbook

accounts.

Table 20 presents the knowledge types encoded by term variants on diffusion in three South

African life sciences textbooks, while Figure 11 models the emergent property of knowledge (also

semantic profile) arising from the description of the process of diffusion. For reasons of space the

titles of the textbooks are abbreviated as SMLS, OSLS and FLS to mean *Study and Master Life

Sciences, Oxford Successful Life Sciences* and *Focus Life Sciences* respectively.

Table 20: Typology of knowledge units in the description of the process of diffusion

Function / Class / Data sources	Token / Noun	Process: Material / Verb	Goal / Nominal group	Value: Place	
				Place alpha	**Place beta**
SMLS	diffusion (SD+)	is (SD-)	movement of molecules of a substance (SD+)(solid, liquid and gas) (SD-)	from a region of high concentration (SD+)	to a region of low concentration (SD+)
OSLS	diffusion (SD+)	is (SD-)	movement of water particles (SD+)	from an area of high concentration(SD+)	to an area of low concentration (SD+)
FLS	diffusion (SD+)	is (SD-)	movement of molecules (SD+)	from a region of high concentration (SD+)	to a region of low concentration (SD+)

The Token slot as depicted in Table 20 is realised consistently by the semantically dense (SD+)

term *diffusion* in all three texts. The Process constituent, conversely, is realised consistently across

the three text sources with the less technical term *is* (SD-). The Goal slot is realised as *molecules*

of a substance (solid, liquid and gas) in *Study and Master Life Sciences, water particles* in *Oxford*

Successful Life Sciences and *molecules* in *Focus Life Sciences.* Here, the doublet, *molecules of a*

substance (solid, liquid and gas) has low semantic density (SD-) because it is contextualised while

water particles and *molecules* have high semantic densities (SD+) because they are abstract. The

constituents that comprise the Value are also realised by a range of terms that have varying degrees

of semantic density. For the Place alpha slot, the terms used range from *region of high*

concentration (SD+) in *Study and Master Life Sciences* and *Focus Life Sciences*, and *area of high*

concentration (SD-) in *Oxford Successful Life Sciences*. Here, the latter has a relatively lower

semantic density compared to the former. The Place beta slot likewise is realised by two variants,

namely: *region of low concentration* (SD+) and *area of low concentration* (SD+). Figure 11

simulates the emergent pattern that evolved from the interaction of variant and invariant terms in

the three textbook descriptions of the process of diffusion.

Knowledge Type	Token	Process: Material	Goal	Value: Place	
				Place α	Place β
SD+					
SD-					
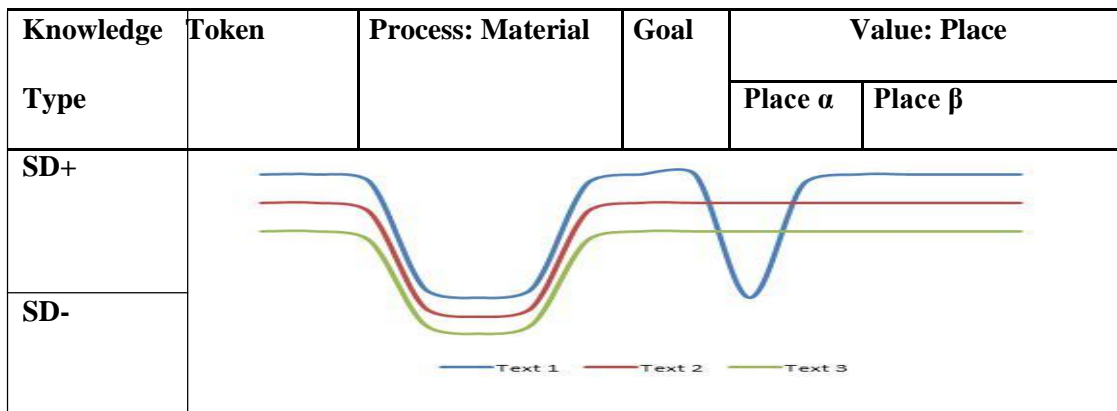
Figure 11: Flow of knowledge in three textbook account of process of diffusion.

On reading Table 20 and Figure 11 concurrently, we see that the SW illustrated in Texts 1 to 3 of

Figure 11 originates from the Token slot that has a term which encodes an abstract knowledge type

(SD+). The wave length moves downwards due to use of a less technical knowledge term,

movement (SD-) in the Process slot across the three text sources. It can be noted that in Text 1,

however, the wave moves further downwards in the Goal slot before assuming an upward shift

that flattens to the last constituent of the clause, the Value slot. In Texts 2 and 3 on the other hand,

the formation of the high semantic flatline originates from the Process slot which further flattens

to the Place beta constituent. The next section describes the types of knowledge unit observed in

the description of osmosis and their realisation in the different constituents of the clause in textual

progression.

Table 21 presents the types of knowledge encoded in terms in three Nigerian textbook accounts of

osmosis while Figure 12 models the trajectory of knowledge (also the semantic profile) resulting

from the interaction of the terms in textual progression.

Table 21: Typology of knowledge units in the description of the process of osmosis

Function	Token	Process: Relational	Goal	Value: Place	
				Place α	**Place β**
New Biology	osmosis (SD+)	is (SD-)	passage of molecules of solvent (SD+)	from a low concentrated solution (SD+)	to a more concentrated solution (SD+)
College Biology	osmosis (SD+)	is (SD-)	diffusion of water molecules (SD+)	from a region of low osmotic pressure (SD+)	to a region of high osmotic pressure (SD+)
Essential Biology	osmosis (SD+)	is (SD-)	flow of water molecules (SD+)	from a region of dilute (SD+) or weak solution (SD-)	to a region of high concentration (SD+)

From the standpoint of knowledge types encoded in terms, we see from Table 21 that the Token slot is realised consistently by the semantically dense term *osmosis* (SD+) across the three text sources while the Process slot is realised across the three text sources by the non-technical term *is.* The Goal slot is realised by two different variants, namely: *molecules of solvent* in *New Biology* and *water molecules* in both *College Biology* and *Essential Biology*. Even though both variants have a high level of abstraction, the term *molecules of solvent* (SD+) has a higher level of abstraction than *water molecules* because it falls within the high–medium level of abstraction in Dimopoulos et al.'s (2005) classification scheme. The Value constituent is also realised by a range of terms that have varying degrees of semantic density. For the Place alpha slot, the terms used range from *low concentrated solution* in *New Biology*, to *region of low osmotic pressure* in *College Biology* and *dilute or weak solution* in *Essential Biology*. In this instance, *low concentrated solution* and *low osmotic pressure* have relatively high semantic density while the conjunctive doublet *dilute or weak solution* has low semantic density because it gives an alternative term for construing dilute solution.

Place beta slot, likewise, is realised by a range of semantically dense terms, namely: *more concentrated solution* (SD+), *region of high osmotic pressure (*SD+) and *region of high concentration* (SD+). Figure 12 presents a dynamic perspective on the interaction of terms across the constituents of the clauses in the three text sources.

Knowledge Type	Token	Process: Relational	Goal	Value: Place	
				Place α	Place β
SD+					
SD-					

Text 1   Text 2   Text 3
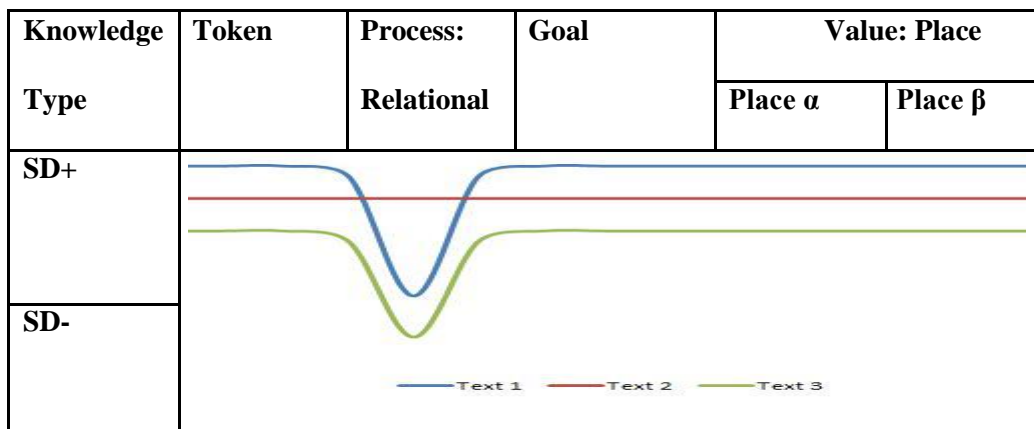
Figure 12: Flow of knowledge in three textbook descriptions of osmosis.

As indicated in Figure 12, Text 1 (*New Biology*) and Text 3 (*Essential Biology)* have a similar SW profile. In other words, both text configurations used a blend of specialised knowledge (SD+) and less specialised knowledge (SD-) in describing osmosis. Conversely, Text 2, *College Biology*, uses specialised knowledge (SD+) across the three constituents of the clause, forming an HSF. Table 22 presents a summary of the SWs in the three Nigerian textbooks**.**

Table 22: Summary of semantic profiles in Nigerian life sciences textbooks

Text source	LSF (%)	HSF (%)	UE(%)	DE(%)	SW(%)	Total
New Biology	0 (0)	4(40)	0(0)	0(0)	6(60)	10(100)
College Biology	0 (0)	3(30)	0(0)	0(0)	7(70)	10(100)
Essential Biology	0 (0)	3(30)	0(0)	0(0)	7(70)	10(100)

The summary of semantic profiles as indicated in Table 21 reveals that none of the text sources have manifestations of low semantic flatline (LSF), upward escalator (UE) or downward escalator (DE). Instead, as the table demonstrates, HSFs and SWs manifest in different proportions. The frequency of HSF as indicated in Table 22 was highest in *New* Biology, with four (4) instances. The lowest occurrence was recorded for both *College Biology* and *Essential Biology* which each

recorded three (03) instances. With regard to profiles exemplifying a SW, the highest manifestation is recorded for both *College Biology* and *Essential Biology* with seven (7) instances each. The occurrence recorded for *New Biology* is four (4) instances, representing sixty per cent (60%). Table 22 presents results on the semantic profiles of the South African life sciences textbooks.

Table 23: Summary of semantic profiles in South African life sciences textbooks

Textbook	LSF(%)	HSF(%)	UE(%)	DE(%)	SW(%)	Total (%)
Study and Master Life Sciences	0(0)	3(30)	0(0)	0(0)	7(70)	10(100)
Oxford Successful Life Sciences	0(0)	2(20)	0(0)	0(0)	8(80)	10(100)
Focus Life Sciences	0(0)	3(30)	0(0)	0(0)	7(70)	10(100)

We see from Table 23 that none of the text sources analysed employed low patterns illustrating LSF, UE or DE in order to mediate content knowledge. It can, however, be noted from the results presented in the table that profiles denoting HSF and SW were used across the three text sources. The frequency of HSF is the highest in *Study and Master Life Sciences* and *Focus Life Sciences* with a count of three (3) representing 30 per cent (30%), while *Oxford Successful Life Sciences* has the lowest frequency, at two (2) representing 20 per cent (20%). With respect to the prevalence of an

SW observed in the South African corpus, *Oxford Successful Life Sciences* is the most frequent, with eight (8) instances representing eighty per cent (80%) of the total. The results in Table 22 indicate that *Study and Master Life Sciences* and *Focus Life Sciences* show less frequency of SW, at seven (7), representing seventy per cent (70%). The next section discusses the implications of the results presented on the distributions of term variants in Nigerian and South African life sciences textbooks and in the different clause constituents of the respective textbook sources.

5.5   Discussion of results

5.5.1   Ratio of variant and invariant terms in Nigerian and South African life sciences textbooks

Results on the frequency ratio of variants and invariant terms (i.e. contaminated and ideal relations) in Nigerian and South African high school life sciences textbooks, as depicted in Table 9, show that the meaning of terms at the individual or parole level activates senses that vary from what is specified at the system level (e.g. a dictionary or a glossary). Although the widespread perception of a univocity principle in Wuesterian terminology has been shown not to be entirely correct (Antia 2001; 2002), this finding contradicts any possible claims of a concept having to be designated only by a term(Antia, 2001 & Antia, 2002).

The findings are compatible with the findings of a number of studies on the pervasiveness of variation in specialised texts (Jacquemin et al., 1991; Tartier, 1991; Daille et al., 1996 and Yoshikane, 1999). A similar finding has also been reported in studies conducted in the context of software localisation (Schmittz, 2007), bilingual translations of specialised texts (Rogers, 2007), legislative discourse (Antia, 2001 & Antia, 2002) and medical texts (Tsuji & Kageura, 2003). The finding on the high prevalence of term variants in the corpora provides further empirical evidence for Keremans's claim that "in specialised texts, authors sometimes deviate from the traditional view of using only one term consistently throughout the text to refer to a particular concept" (Keremans (2010: 1–2).

5.5.2   Typology of term variants in Nigerian and South African life sciences textbooks

The results on the dynamics of terminology in Nigerian and South African life sciences textbooks further showed that term variation manifests as Type 1 variation (or contamination of similarity),

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Type 2 variation (or contamination of inclusion) and Type 3 variation (or contamination of intersection) in both Nigerian and South African life sciences textbooks. In previous research, Type 2 variation is subsumed under Type 1 or synonymy, probably due to their morphological and syntactic structures (Dialle, 1996, 2005; Fernandez et. al, 2002). Type 3 variation appears to be an entirely new construal of term variation, however, because it cannot be subsumed under the category described in Dialle (1996; 2005), nor does it fit into the typology proposed by Fernandez et al. (2002). Type 3 variation or contamination of intersection has some semblance with near synonymy when interpreted as continuous or intermittent variation, as in the example of "seep" and "drip", where the latter is an intermittent event while the former is the continuous flow or leakage of a liquid (Edmond & Hirst, 2002). It may also be viewed as coordination which, according to Jacquemin & Royauté (1994), results when for instance, *inflammatory and erosive disease* and *inflammatory joint disease* are used interchangeably. In this example, the latter fails to activate the other characteristics of inflammatory and erosive diseases related to the inflammatory lesions in the mucous lining of the stomach (see Elta et al, 1987).

5.5.3 Distribution of term variants in Nigerian and South African life sciences textbooks

The results of the analysis further showed that the distribution of Type 1, Type 2 and Type 3 variations in Nigerian and South African life sciences textbooks co-occur with equal frequency. In other words, for both the Nigerian and South African textbooks that were analysed, Type 1 variation occurred the most, followed by Type 2 variation while Type 3 variation occurred the least. Results indicating a similar quantitative tendency in the distribution of the different typology of term variants as identified in the life science textbooks in this study are not compatible with the findings reported by Groves (1995) who partly replicated Yager (1983) and estimated a range of 4 – 5.7 terms per page. This figure is about half of the 10 – 18.4 range earlier estimated by Yager

(1983) and half of the 2.8 – 9.5 terms per page estimated by Evans (1976). One possible explanation for the manifestation of this pattern across text sources might be attributable to the fact that the topics analysed have similar learning outcomes and are meant for the same grade level. A further possibility is that it might not be unconnected to the approach adopted in this study. It is obvious that, while previous research estimated the terminology load in entire disciplinary texts (Freixa et al., 2011) or in genres and subgenres of specialised texts (Gerzymisch-Arbogast, 2008), the emphasis of this study was on specific topics.

5.5.4   Distribution of term variants in the clause constituents of Nigerian and South African life sciences textbooks

Results on the quantitative tendencies of the different typology of term variants identified in the clause constituents of Nigerian and South African life sciences textbooks indicated an uneven distribution of term variants in the three constituents of the clauses analysed. The results specifically showed that the Circumstances slot had the highest frequency of twenty (20) in the Nigerian corpus while the Participant slot had the highest in the South African corpus. In Both the Nigerian and South African corpora however, the Process slot had the least frequency. This finding is perhaps not surprising, because unlike other functional categories which are nominal, adjectival or adverbial groups, the Process involves only verbs. This finding is however a marked departure from that reported in Evans (1976); Yager (1983); Gerzymisch-Arbagast (2008) and Freixa et al., (2011). This is because in all these studies, the clause level of analysis is neglected.

5.5.5   Flow of knowledge units in the clause constituents of Nigerian and South African life sciences textbooks

Results on the emergent patterns resulting from the interaction of knowledge types in the sixty (60) clauses analysed indicated that none of the Nigerian and South African life sciences textbooks

had any instances of semantic profiles with LSF, UE or DE. That is to say, the textbooks used mostly technical vocabulary (terms) rather than non-technical vocabulary in describing scientific concepts and phenomena. The findings confirm results on prevalence of the use of technical vocabulary in science textbooks reported in previous research (Halliday & Martin, 1993; Groves, 1996; Snow, 2005). It also confirms the results of a sociolinguistics approach to the analysis of secondary school science subjects by Dimopoulous (2005) where it was found that lower grade Greek science textbooks are characterised by higher levels of content specialisation but that physics textbooks have the highest degree of abstraction, if one compares them with chemistry and biology textbooks. This finding, however, contradicts the views of Maton (2013) who argued that knowledge building is not a semantic flatline but rather the ability to transfer knowledge across context and through time.

The findings further indicated that profiles with HSFs are prevalent in the clauses of both the Nigerian and the South African textbooks. What this implies is that the textbooks analysed tend to use technical terms or power words (Martin, 2013) consistently across the constituents of the clauses. This finding confirms Bernstein's claim that horizontal discourses, e.g. physics, chemistry and biology, encode knowledge that is abstract compared to vertical discourses, where the knowledge encoded is contextualised. The finding contradicts a recent finding by Thonney (2016) that the vocabulary load in biology textbooks is not as high as has often been reported and that physics has a higher vocabulary load than chemistry and biology.

The results further indicated the prevalence of semantic profiles with SWs in both Nigerian and South African textbooks. This fact means that content knowledge is mediated in the textbooks by

blending specialist and non-specialist vocabulary across the constituents of clauses. The finding that both Nigerian and South African textbooks alternate specialised and non-specialised terms is compatible with the notion of cumulative knowledge building – by which is meant the transfer of knowledge between context and over time (Maton, 2013). The finding is also in consonance with the view that vocabulary depth and growth follow a developmental trajectory that expands and deepens (Biemiller, 2001) and accrues over time (MacGregor et al., 2007).

5.6   Conclusion

This chapter presented and discussed results on the typology and distribution of term variants in Nigerian and South African life sciences textbooks for high school. Three typologies of term variants were developed, based on insights from the context-specific term model proposed by Gerzymisch-Arbogast (2008). They include Type 1 variation or contamination of similarity, Type 2 variation or contamination of inclusion and Type 3 variation or contamination of intersection. The chapter further used descriptive statistics to present results on the distribution of the identified three typologies of term variant, which co-occurs with the same frequency across the Nigerian and the South African life sciences textbooks. Results of the findings further indicated that the terminology in Nigerian and South African Life Sciences textbooks is dynamic and not static, hence prone to variation across the elements of the clauses analysed.

Results of the findings on the pervasiveness of term variants in the constituents of the clauses analysed has been previously reported in a number of studies conducted in the context of monetary economics (Gerzymisch-Arbogast, 1996), software localisation (Schmitz, 2007), translations of German and English texts (Rogers, 2007), legislative discourse (Antia, 2000) and medical texts (Tsuji & Kageura, 2003). But unlike previous research where the emphasis on the manifestations

of term variants is in an entire text (Evans, 1976; Gerzymisch-Arbogast, 1996), sub-genres of a specialised text (Bertels & Speelman, 2014) and specific pages of an entire text (Yager, 1983; Groves, 1995), we elect to take a different tack by analysing the dynamics of terminology at the clausal level of analysis. A qualitative description of the interrelationship between the different types of knowledge units (terms) encoded in life sciences textbooks was attempted using legitimation code theory. Results of the analysis of the nature and use of terms in Nigerian and South African corpora led to the following conclusions:

- Term variation in life sciences textbooks can be classified according to categories outlined in the context-specific term model proposed by Gerzymisch-Arbogast (1996 & 2008). Results from the qualitative analysis of the nature of term variants in Nigerian and South African life sciences textbooks fostered the development of three typologies of term variant. They are Type 1 variation (or contamination of similarity), Type 2 variation (or contamination of inclusion) and Type 3 variation (or contamination of intersection).

- The three typologies of term variant that were identified in the corpora co-occurred with the same frequency in Nigerian and South African textbooks but varied in their distributions in the Participant, Process and Circumstances constituents of the clauses analysed.

- Content knowledge in Nigerian and South African life sciences textbooks is mediated by blending specialised and non-specialised vocabulary and the different textbooks also employ patterns predicted by legitimation code theory to achieve this goal.

The next chapter discusses the significance of term variation to achievement in science by Nigerian and South African learners.

CHAPTER SIX

SIGNIFICANCE OF LANGUAGE PROFICIENCY AND SCIENCE COMPETENCE TO THE PERFORMANCE OF NIGERIAN AND SOUTH AFRICAN LEARNERS IN TEST ON PROCESSING VARIANT TERMINOLOGY

6   Introduction

This chapter discusses the third, fourth and fifth objectives of the study: first, to determine the relationship between learners' language competence and their performance in tasks on processing variant terminology; second, to determine the relationship between their science competence and performance in tasks on processing variant terminology and third, to ascertain whether a significant difference exists in the performance of Nigerian and South African learners in processing variant terminology. Three null hypotheses were formulated to determine whether achievement scores of learners in the test administered can be associated with their profiles (determined in terms of strength or weakness) in English language and science. The relationships between the language and the science competences of learners were tested using the Pearson product-moment correlation coefficient test while a chi-square statistical tool was used to compare the performance of Nigerian and South African learners. Before presenting the results related to these objectives, we shall first present the aggregate scores of the performance of Nigerian and South African learners in the test administered.

6.1   Overview of the performance of Nigerian and South African learners in a test on processing variant terminology

This section presents results on the performance of Nigerian and South African learners in the test administered on processing variant terminology. The data presented will be used to determine whether there is a correlation between the performance of learners and their competences in

language and science. The data will also be used to determine whether there is any correlation between the performance of Nigerian learners on the one hand and South African learners on the other. Tables 24 and 25 present an overview of the performance of individual Nigerian and South African learners in a ten-item test.

Table 24: Performance of Nigerian learners per question in a ten-item test on processing variant terminology

Topic	Special science school		Special arts school	
	(√ %)	(X %)	(√ %)	(X %)
1 Nervous coordination	31(86)	14(14)	21(60)	14(40)
2 Nervous coordination	11(31)	24(69)	22(62)	13(38)
3 The cell	05(14)	30(76)	11(31)	24(69)
4 The cell	30(85)	05(15)	22(62)	13(38)
5 Plant nutrition	31(86)	04(14)	26(74)	09(26)
6 Plant nutrition	30(85)	05(15)	24(68)	11(32)
7 Nitrogen cycle	28(80)	07(20)	12(34)	23(66)
8 Nitrogen cycle	24(68)	11(32)	17(48)	18(52)
9 Respiration	15(42)	20(58)	22(62)	13(38)
10 Respiration	17(48)	18(52)	11(31)	24(69)

Note: (√ = correct answer; X = incorrect answer, % = percentage)

For ease of comprehension, the tick (√) and percentage (%) signs signify percentage of correct answer on each topic while the fail (x) and percentage(%) notations signify the percentage of incorrect answer per topic. The aggregate scores and percentages of learners who got the correct and wrong answers per test question presented in Table 24 indicated that one third of learners from a special science school (i.e. eleven learners) gave an incorrect answer to five out of the ten questions. The mean pass rate for the school is sixty-three percent (63%) while the mean failure rate is thirty-seven percent (37%). Results of the performance of Nigerian learners from a secondary school that runs an art curriculum indicated that one third of the learners (i.e. eleven learners out of thirty-five) who participated in the study gave incorrect answers in nine questions out of ten. The mean pass and fail rates, displayed in Table 24, were fifty-four percent (54%) and

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forty-six percent (46%) respectively. Let us turn to Table 25, which presents results on the performance of South African learners.

Table 25: Performance of South African learners per question in a ten-item test on processing variant terminology

Topic	Science school (Dinaledi)		Special arts school	
	(√ %)	(X %)	(√ %)	(X %)
1 Nervous coordination	29(83)	16(17)	27(77)	08(23)
2 Nervous coordination	28(80)	07(20)	20(57)	15(43)
3 The cell	20(57)	15(43)	21(60)	14(40)
4 The cell	27(77)	08(23)	12(34)	23(66)
5 Nitrogen cycle	11(31)	24(69)	13(37)	22(63)
6 Nitrogen cycle	09(25)	26(75)	06(17)	29(83)
7 Blood circulation	20(57)	15(43)	20(58)	15(42)
8 Blood circulation	21(60)	14(40)	23(66)	12(34)
9 Water transport in plants	29(83)	06(17)	15(42)	20(58)
10 Water transport in plants	25(71)	10(29)	13(37)	22(63)

Note: (√ = correct answer; X = incorrect answer, % = percentage)

Results on the performance of South African learners from a special science (Dinaledi) school as presented in Table 24 indicated that one third of the study participants (i.e.11 learners) gave wrong answers to four out of the ten questions in the test on processing variant terminology. Nonetheless, as indicated in the table, the mean pass and fail rates were sixty-two percent (62%) and thirty-eight percent (38%) respectively. The results of South African learners from a special arts school, presented in Table 24, indicated that a quarter of the learners who participated in the study gave wrong answers to three questions out of the ten. The cumulative mean of those who gave correct answers is forty-nine percent (49%) while the mean of those who gave wrong answers is fifty-one percent (51%). Having presented the individual scores of learners, let us now present the results of the Nigerian and South African teams that participated in the study.

Table 26: Performance of Nigerian teams in a test on processing variant terminology (√ = correct answer; x = incorrect answer; %=percentage)

Topic	dialogue Think-Aloud Protocol teams											
	Arts-based school type						Science-based school type					
	A	B	C	D	E	(%)	A	B	C	D	E	(%)
1 Nervous coordination	√	√	√	√	√	100	√	x	√	√	x	60
2 Nervous coordination	√	√	√	x	x	60	x	√	x	√	√	60
3 The cell	√	x	√	x	x	40	√	√	√	√	√	100
4 The cell	√	√	√	√	√	100	√	√	√	√	x	80
5 Plant nutrition	√	√	x	√	√	80	√	√	x	√	√	80
6 Plant nutrition	x	√	√	√	√	80	√	√	√	√	√	100
7 Nitrogen cycle	x	√	x	x	√	40	x	√	x	√	x	40
8 Nitrogen cycle	√	√	x	√	√	80	x	√	x	√	√	60
9 Respiration	x	x	√	x	x	20	√	√	√	√	√	100
10 Respiration	x	√	x	x	x	20	x	√	x	√	x	40
	06	08	06	05	06	50	06	09	06	10	06	70

Table 27: Performance of South African teams in a test on processing variant terminology (√ = correct answer; x = incorrect answer)

Topic	dialogue Think-Aloud Protocol teams											
	Arts-based school type						Science-based school type					
	A	B	C	D	E	(%)	A	B	C	D	E	(%)
1 Nervous coordination	√	√	√	√	√	100	√	√	x	√	√	80
2 Nervous coordination	√	√	√	√	√	100	√	√	x	x	√	60
3 The cell	x	√	√	x	x	40	√	x	x	√	√	60
4 The cell	x	x	x	x	√	20	√	√	√	x	x	60
5 Nitrogen cycle	x	√	x	x	√	40	x	√	√	x	x	40
6 Nitrogen cycle	x	x	x	x	x	00	x	x	x	x	x	00
7 Blood circulation	√	x	√	x	√	60	√	√	√	x	√	80
8 Blood circulation	x	√	√	√	√	80	√	√	x	√	√	80
9 Water transport	√	√	√	x	x	60	√	x	√	√	√	80
10 Water transport	√	√	√	x	x	60	x	x	x	x	√	20
	05	07	08	03	06	51	07	06	04	06	07	60

As depicted in Table 26, there are only two instances, i.e. questions 1 and 4, where participants from the arts secondary school in Nigeria gave accurate answers. Participants recruited from the Nigerian science secondary school recorded one hundred percent (100%) for three questions: 3, 6 and 9. The lowest results for the performance of Nigerian learners recruited from the arts secondary school, twenty percent (20%), was recorded for questions 9 and 10; whereas the lowest result for those recruited from the science secondary school, forty percent (40%) was recorded for questions 7 and 10.

In Table 27, the results of the performance of South African participants who wrote the test in groups indicated that learners from the arts-based school recorded a 100% achievement rate in questions 1 and 2. The remaining questions recorded scores ranging from zero (00%) in question 6 to eighty percent (80%) in question 8. For South African learners from special science school or Dinaledi school, the highest performance rate is eighty percent (80%). This performance was recorded for questions 1, 7, 8 and 9. As found among learners from the special arts school, zero percent (00%) was recorded for question 6 among participants from the special science school.

The next section of the study will use the data presented in Tables 24 to 27 to determine the significance of learners' language proficiency and science competence in test on how to process and respond to terminology variation. The test that was administered was designed to assess the abilities of learners in processing term variants in life sciences textbooks. The data presented will also be used to determine the possibility of a significant relationship between the performance of Nigerian and South African learners.

6.2 Correlation between language proficiency and achievement in a test on processing variant terminology among Nigerian and South African high school learners

In order to address the third objective of the study on whether a correlation exists between performance in tasks on terminology processing and the language proficiency of learners, a Pearson product-moment correlation test was computed to test the null hypothesis which sought to assess the relationship between the two variables. The hypothesis stated that:

$H0_1$: Perceived competence of learners in English language cannot predict achievement in scientific tasks involving identifying and resolving terminology variation.

The purpose of the empty or null hypothesis was to dissociate achievement which has been traditionally attributed to the proficiency levels of learners. Results from the computation of the Pearson product-moment correlation test are presented in Table 28.

Table 28: Correlation between science competence and achievement in test on identification and resolution of term variation

Variables	Type of hypothesis	Pearson coefficient
Language competence and Achievement in test	(1 Tail) Sig. 0.05	**r** = -0.7603

Note: Correlation coefficient value (StrongEng r = -0.7603, $p < 0.05$)

As depicted in Table 28, the results of the Pearson product-moment correlation indicated a correlational coefficient value (StrongEng r = -0.7603, $p < 0.05$) suggesting a negative correlation

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between language competence and achievement in the test on terminology processing. What this means is that the proportion of total variance in achievement of learners on the test involving identification and resolution of terminology variation cannot be attributable to the language competence of learners. In view of this inference, the hypothesis that the competence of learners in the English language cannot predict achievement in a test on how to identify and respond to term variation is accepted. Let us now consider the second hypothesis on the correlation between the science competence of learners and achievement in the test administered.

6.3 Correlation between science competence and achievement in a test on processing variant terminology among Nigerian and South African high school learners

In order to achieve the fourth objective of the study – to determine whether the science competence of learners will be a correlate of achievement in a test on processing variant terminology, we also proposed a null hypothesis which stated that:

H0$_2$: Perceived competence of students in science cannot predict achievement in tasks involving identification and resolution of terminology variation.

A Pearson product-moment correlation coefficient test was computed to assess the relationship between achievement in a test on processing variant terminology and the science competence of learners. Results from the computation of the Pearson product-moment correlation coefficient test are presented in Table 29.

Table 29: Correlation between science competence and achievement in test on identification and resolution of term variation

Variables	Type of hypothesis	Pearson coefficient
Science competence and Achievement in test	(1 Tail) Sig. 0.05	**r** = 0.2050

Note: Correlation coefficient value (StrongSc **r** = 0.2050 *p > 0.05*)

The results of the Pearson Product-moment Correlation Test as presented in Table 29 indicated a coefficient value (StrongSc r = 0.2050, *p* > 0.05) signifying a weak positive correlation. In other words, high competence of learners in science was correlated with high achievement in the test on how to identify and respond to term variation. Consequently, the null hypothesis which states that competence of learners in science cannot predict performance in a test on how to identify and respond to term variation is rejected. The next section presents the results of a chi-square test on the correlation between the performance of Nigerian and South African learners in tasks on processing term-variant terminology.

6.4 Correlation between the performance of Nigerian and South African high school learners in a test on processing variant terminology

A third null hypothesis was formulated to address the fifth objective of the study, namely whether a significant difference exists in the performance of Nigerian and South African learners in the test on processing variant terminology. The hypothesis states that:

H0$_3$: There will be no significant difference in the performance of Nigerian and South African learners in a test on processing variant terminology.

The proposed hypothesis which sought to determine whether there is a correlation between the performance of Nigerian and South African learners in tasks on processing variant terminology was tested using a chi-square statistical test. This test was preferred to others because the variables inherent in the data were not categorical with respect to the degree of proficiency or competence. In order to test the proposed hypothesis, the mean indices of pass and fail rates of individual and groups of learners who participated in the test administered were used to determine whether the performance of Nigerian and South African learners in the test was significantly similar or different. Table 30 presents the results of the chi-square statistics whereas Table 31 presents the results of the Fisher Exact statistical test.

Table 30: Correlation between the performance of individual Nigerian and South African learners in test on terminology processing

Type of learners	Mean pass rate (%)	Mean failure rate (%)	Row marginal total (%)
Nigerian learners	41(40)(0.02)	29 (30)(0.03)	100
South African learners	31(40)(0.02)	31(30)(0.03)	100

Note: The chi-square statistic is 0.1167. The *p*-value is 0.7326478. This result is not significant at $p < .05$.

Results of the chi-square test as presented in Table 30 indicate a negative correlation between the performance of Nigerian and South African learners in the test on processing variant terminology, in other words, the difference in performance of Nigerian and South African learners is not significant ($x^2 = 0.1167, p > 0.05$). Based on this inference, the proposed null hypothesis that no significant difference exists in the performance of Nigerian and South African learners in tasks on terminology processing was upheld. To further validate these findings, we used the Fisher Exact test (because of the small sample – only fifteen per school and thirty participants per country) to determine whether the relationship between the performance of Nigerian and South African learners would be significant. Table 30 presents the results of the computation of this test.

Table 31: Correlation between the performance of Nigerian and South African teams in test on terminology processing

Type of team	Mean pass rate (%)	Mean failure rate (%)	Row marginal total (%)
Nigerian Teams	60(57.5)	40(42.5)	100
South African Teams	55(58.0)	45(43.0)	100

Note: The Fisher Exact test statistic value is 0.479083. The result is not significant at $p < .05$.

Results of the Fisher Exact test statistics as presented in Table 30 indicated no significant relationship (p= 0.479083; Fisher Exact test) between the performance of Nigerian and South African learners. This finding corroborated the results of the chi-square test presented in Table 30, suggesting that there is insufficient evidence to substantiate a difference between the performance of Nigerian and South African learners in the test administered. Based on this inference, the proposed null hypothesis that no significant difference exists in the performance of Nigerian and South African learners in a test on processing variant terminology is upheld.

6.5   Discussion of results

The findings of the study show that proficiency in English do not confer advantage when it comes to processing term variants in high school life sciences textbooks. The findings contradict results of studies that have identified language proficiency as the sole framework for overcoming barriers to the understanding of science (Maier & Schweiger, 1996; Audu, 2005; Fakeye & Orgunsiji, 2009). This does, however, provide further empirical evidence justifying the need to distinguish between Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP) (Cummins, 2000).

The finding that competence in science (rather than English language) fosters achievement in the test administered contradicts claims in Nigerian and South African language education discourse associating proficiency in English language with achievement in science (Howie, 2002; Howie & Plomp, 2003; Audu, 2005). The finding aligns with recent thinking in science education that suggests the need for scaling up learners' science literacy skills rather than their language proficiency skills (see Nicolis & Prigogine, 1987; Kail & Pellegrino, 1989; Kauertz & Fischer, 2006; Commons, 2007). A broader scope of language proficiency from this standpoint would ideally comprise, among others, the ability to use mental models to comprehend texts (de Beaugrande, 1989; Sowa, 1995), the ability to detach content from contexts (Lijnse, 1990) and the ability to analyse thematic patterns (Thompson, 2015; Antia & Kamai, 2016), as well as the ability to identify different kinds of knowledges that are linked by functional relations (Schleppegrell, 2004; Kauertz, et. al, 2012; Resnick & Ford, 2012). The finding is also a perspective shared by Lemke, who argued that "learning science is not just the mastery of vocabulary […] but rather the knowledge of network of relationships among scientific concepts and knowledge of how language is used in a field or context" (Lemke, 1996:13). It also corroborates the "Asian Effect" that was observed among Japanese, Chinese and Korean learners who had poor proficiency in English but performed better than the American learners in science and mathematics achievement tests administered in English (Peng & Wright, 1994; Sun, 1998).

Results of both the chi-square test (x^2 = 0.474486, $p > 0.05$) and the Fisher Exact test (p= 0.479083; Fisher Exact test) suggest a negative correlation between the performance of Nigerian and South African learners in the test on processing variant terminology in life sciences textbooks. These findings contradict results reported in Atebe & Schaffer (2010) where it was shown that Nigerian

learners had a weaker understanding of basic geometry terminology than their South African counterparts. They also contradict results reported in the World Economic Forum Report 2010 where the performance of South African learners in science is positioned at 146th out of 148 countries, behind the likes of Haiti, Lesotho, Chad, Zimbabwe, Nigeria, and Kenya(See.Schwab, 2010)

Despite the useful insights derived from the quantitative analysis of the relevance of language proficiency and science competence to achievement in a test on processing variant terminology, our knowledge about the underlying cognitive processes of learners in the tests administered is still inadequate. We also do not know the strategy learners adopt to respond to challenges posed by term variation. The next section presents findings derived from a qualitative method which is intended to complement the results of the quantitative method already discussed. The analysis is underpinned by insights from the context-specific term model proposed by Gerzymisch-Arbogast, Lemke's construct of thematic pattern analysis and Maton's legitimation code theory semantics.

6.6 Cognitive effects of term variation on the performance of Nigerian and South African learners: perspectives from terminology, text semantics and legitimation code theory The
previous section described the effects of terminology variation on the performance of Nigerian and South African learners based on descriptive statistical methods. The results presented in this section address the extent to which Gerzymisch-Arbogast's theory of term contamination, Lemke's construct of thematic pattern and Maton's legitimation code theory can validate the observed patterns in the cognitive processing of term variation. In what follows, protocol data illustrating how term variation challenged participants and the strategies they deployed to

surmount the challenge(s) is presented and discussed. Let us now consider the first set of protocol data describing the challenges Nigerian and South African learners encountered during the tests.

6.6.1 Challenges Nigerian and South African learners face in processing variant terminology in science textbooks

Protocol data 1 presents a transcript of the deliberations of two participants, Nemzieu and Baya, (not their real names) on question 9 (i.e. osmosis under the topic: The cell and its environment). The test question given to the participants required them to answer by indicating (Yes) or (No) to the question of whether osmosis is the passage of solvent from a dilute solution to a more concentrated solution. The participants were given a reference (that treats the same topic) to consult before answering the question. The reference text is: *Osmosis is the movement of water molecules from movement of water particles from a dilute solution to a more concentrated solution.* The test question on the other hand is: *Osmosis is the passage of solvent from a dilute solution to a more a more concentrated solution. True or False?*

The analysis of the text configurations given to the learners indicate that, the term for the Process slot, i.e. *movement* was used in the reference text, but in the test question, the term used was *passage.* For the Goal slot, the term *water molecules* was used in the reference text while the *solvent* was used in the test question. Similarly, for the Place alpha slot in Circumstance, the term *hypotonic* was used in the reference text while *concentrated solution* was used in the test question. From the standpoint of the context-specific term model proposed by Gerzymisch-Arbogast (2008), the typology of variation exemplified involving *movement* and *passage; solvent* and *water molecules* is called contamination of similarity which for the purposes of this study is referred to

as Type 1 variation. The deliberation of two participants depicting how they responded to Type 1 variation is presented in Protocol data 1.

Text segment	Protocol data 1: Verbalisation on osmosis by Nemzieu and Baya
1	**Nemzieu:** The answer is false. I'll go for false because the question says
2	osmosis is the passage of solvent from a dilute solution to a more concentrated
3	solution while … while the text given here (referring to the reference text) it
4	says […] osmosis is defined as the movement of water molecules from a dilute
5	solution into a more concentrated solution through a semi-permeable
6	membrane.
7	**Baya:** The answer is false because in the passage osmosis is said to be the
8	movement of molecules from hypotonic to hypertonic solution through a
9	selectively permeable membrane. This is not what is in the question and that
10	makes the answer to the question to be wrong.

As depicted in Protocol data 1, Nemzieu gave an incorrect answer to the test question and reasoned in lines 1 to 4 that: "the question says osmosis is the *passage of solvent* from a dilute solution to a more concentrated solution while the text given here (referring to the reference text) it says […] osmosis is […] *the movement of water molecules*". Baya's justification for the choice of his answer, which turns out also to be wrong, is that *hypotonic solution* was used in the reference text while *dilute solution* was used in the test question. The fact that both the participants got the wrong answer and justified their answers by arguing that the use of term variants was responsible for their choice of answers suggests that the use of synonyms in the test question and the reference text misled the learners. Let us turn to question 6, which tests participants' knowledge of the relationship between neurones and nerves.

Question 6, on the structure of neurones, is also worded to pose a challenge of synonymy involving the use of the term *neuron* in the test question and *nerve cell* in the reference text. The reference text is as follows: *Sensory neurons carry impulses from the receptors (nerve endings or sense organs, such as eyes, ears, nose, tongue and skin) to the brain and spinal cord*. The question to be answered is as follows: *A Nerve cell that transmit messages from Muscle or Gland to the Central Nervous System is called sensory neuron True or False?* We see from Protocol data 2 that Nahinda (a fictitious name for a member from group 1) got the wrong answer due to her inability to establish a synonymic relation between *nerves* and *processes* in the test question and the reference text respectively. The challenge encountered in processing variant terminology by Nahinda is illustrated in Protocol data 2.

Text segment	Protocol data 2: Verbalisation on the structure of neurones by Nahinda
1 2 3 4 5	(Thinking aloud…) The nerve fibres are projections and the other one says processes are long outgrowths that conduct nerve impulses. The answer is false, it's kind of confusing […] it does not make sense because they say here (referring to the reference text*)* nerve fibres are projections, now they say here (referring to the test question) processes are projections.

With respect to the cognitive effects of term variants, we see from Protocol data 2 how the use of *nerve fibres* and the conjunctive doublet *processes and projections* confused the learner. The confused state of the learner is evident in lines 3 to 8: "It's kind of confusing […] it does not make sense because they say here (referring to the reference text) *nerve fibres are projections,* now they say here (referring to the test question) *processes are projections*". This finding again validates the claim that term variation has a negative effect on learners.

To further describe the cognitive processes of participants while dealing with term variation, we analysed Protocol data 3 in order to illustrate how participants gave the wrong answers to test questions due to term variation. The test question required participants to provide an answer to the question on whether diffusion is the movement of particles or molecules of solid, liquid and gas. To answer question 3, learners were also given a reference text to consult. The reference text is as follows: *Diffusion is the movement of solid, liquid and liquid from an area of high concentration to an area of low concentration, down a concentration gradient*. The question to be answered on the other hand is as follows: *The movement of molecules of a substance (gas or liquid) from a region of higher concentration of that substance to a region of lower concentration of that substance that is down a concentration gradient is diffusion True or False?*

The reference text made use of the term *solid, liquid and gas* in the description of diffusion. The test question, on the other hand, used the term variant *gas or liquid*. The typology of contamination illustrated by this is called contamination of intersection. Protocol data 3 presents the cognitive states of participants' deliberation on how to resolve Type 3 variation.

Text segment	Protocol data 3: Verbalisation on diffusion by Ijasini, Siyabonga and Athi
1	**Ijasini:** (Student reads the reference text where the term *solid, liquid and*
2	*gas* is used to refer to particles). The question here says the movement of
3	particles in brackets (gas or liquid). They did not indicate the word solid.
4	They are talking only about gas or liquid. So I go for false.
5	**Siyabonga:** Solid molecules? (A rhetorical question). Um … I am usually
6	familiar with gas and liquid, not solid molecules.
7	**Athi:** Aah ah (shaking the head in disagreement). I think it's false. Yeah, it's
8	false … because diffusion deals with gases and liquid not solids.

Analysis of the cognitive states of participants as depicted in Protocol data 3 indicated, in lines 4 to 5, that Ijasini recognised the problem of term variation: "*solid, liquid and gas* was used in the reference text, while *gas and liquid* was used in the test question. So I go for false". The second and third participants (Siyabonga and Athi) were both doubtful of whether the correct answer should be "true" or "false". In line 6, Siyabonga reads the test question and reference text aloud (probably as a way of self-explaining or building understanding of the text) and concludes that: "Um I am usually familiar with *gas and liquid* not *solid* molecule". The third respondent (Athi) in line 9 wrongly concludes that: "Yeah it's false…because diffusion deals with *gases and liquid* not *solids*". We see from the results presented and discussed in Protocol data 1, 2 and 3 that term variation impedes learning, especially in an assessment context. The observations from the protocol data that term variation poses comprehension challenges has also been reported by Tendai (2015) whose study found that learners were not able to engage with biology terms because of their abstract nature and that the learners lacked the formal reasoning skills required to support understanding (Tendai, 2015: 1). The conclusion that term variation impedes learning, however, needs to be cautiously interpreted because a large body of research evidence has shown that term variation can indeed be leveraged to foster learning (Maton, 2013; Matriolugo et al., 2014). Continuing with this line of argument, we present results on the metalinguistic strategies learners adopted to surmount challenge(s) posed by term variation and the "formal reasoning" (Tendai, 2015) they give to support their choices of answer to the test questions administered.

6.6.2 Strategies Nigerian and South African learners adopt to respond to terminology variation in science textbooks

Thus far, three sets of protocol data were described in order to illustrate the nuisance value of term variation in learners' attempts to process written science. We described how term variation misled

learners and the cognitive states of respondents while responding to the test. This section presents protocol data describing the strategies participants deployed to resolve the problems posed by term variation. To this effect, protocol data depicting participants' correct reasoning or right answer will first be presented. This will be followed by protocol data illustrating the strategies learners deployed in order to solve the problem posed by term variation.

In Protocol data 4, a participant (Abrahams) was responding to the question on osmosis. The reference text is as follows: *Osmosis is the movement of water molecules from movement of water particles from a dilute solution to a more concentrated solution.* The question to be answered is as follows: *Osmosis is the passage of solvent from a dilute solution to a more a more concentrated solution. True or False?*

The participants in the focus group discussion of which Abrahams was a member were required to identify a relationship of synonymy between the term *passage* and its variant *movement* in the Process slot of the clause constituent. Participants were also expected to resolve term variation involving another term, *water*, and its variant *solvent* in the Goal slot. The participants got the correct answer to the question despite the challenge which the test question posed, as can be seen from the transcript of their deliberations in Protocol data 4.

Text segment	Protocol data 4: Verbalisation by Abrahams on osmosis
1	**Abrahams:** Umh … from the question here, osmosis is the passage of
2	molecules of solvent from a dilute solution to a more concentrated solution
3	and here, osmosis is defined as the movement of water particles from a dilute
4	solution to a more concentrated solution. Solvent here represents water or
5	the liquid part of the solution so the answer must be true.
6	**Tumi**: The answer is true.
7	**Adler:** I agree with Abrahams' answer.

As indicated in lines 4 to 6 in Protocol data 4 and 5, term variation was not a problem as the team leader (Abrahams) got the correct answer to the test question by substituting the terms *solvent* and *water* with a simplified synonym, *liquid*, in line 4: "*Solvent* here represents *water* or the *liquid part of the solution*". From the standpoint of legitimation code semantics the strategy involves weakening the semantic density (SD-) of the term *solvent* by simplifying the meaning of *solvent*. In Protocol data 5, Sandra was processing question 4 on diffusion under the topic "The cell and its environment". The question required participants to indicate a (Yes) or (No) answer to the question as to whether the movement of molecules of gas, solid and liquid from a region of higher concentration of that substance to a region of lower concentration of that substance was diffusion. The rationale for the question is to test whether the participants will be able to identify hyponym-hyperonymic shift or distinguish between the use of a generic term (molecules) and the use of specific terms (solid, liquid and gas) in different text configurations.

Text segment	Protocol data 5: Verbalisation by Sandra on diffusion
1	**Sandra:** The answer is true, because it is stated here (referring to the reference
2	text) that diffusion is the movement of molecules, while in the question, it is
3	said to be the movement of gas or liquid. Gas or liquid may be in form of ions
4	in the human body and they are in molecules.
5	**Emma:** I don't know… I am lost here. I think it's true.
6	**Tim**: I think it's true.

As depicted in Protocol data 5, two participants found the test question challenging at first. We see this in Emma's doubtful response in line 5: "I don't know… I am lost here. I think it's true". However, in lines 1 to 3 it can be observed that Sandra was able to recognise term variants in the test question and the reference text: "it is stated here (referring to the reference text) that diffusion is the movement of *ions or molecules*, while in the question, it is said to be the movement of *gas*

or liquid". The participant went ahead to get the right answer to the question despite the variation in use of terms by activating extra textual knowledge, as indicated in lines 3 to 5: "gas or liquid here may be in form of ions in the human body and they are in molecules". This metalinguistic strategy displayed by Sandra turns out to be beneficial to Tim, who used the inference as a basis for the choice of his answer.

Protocol data 6 further illustrates the use of another metalinguistic strategy, reformulation, by a participant (Leon) to surmount the challenge posed by term variation. The participants, in the focus group of which Leon was the team leader, were required to establish a relationship of synonymy between *denitrifying bacteria* and *pseudomonas denitrificans.* The reference text is as follows: *Denitrifying bacteria breaks down nitrates to release gaseous nitrogen. They do so to obtain oxygen for their respiration. Denitrifying bacteria are most active in waterlogged or badly drained soils. The question to be answered is as follows: Pseudonomas denitrificans converts amino compounds to atmospheric nitrogen.* True or False? Protocol data 6 highlights the thought processes of learners during the test.

Text segment	Protocol data 6: Verbalisation on denitrification by Benny, Reddy and Leon
1	**Benny:** Aaam. I must confess this question is quite confusing. What is
2	mentioned here (referring to the reference text) is denitrifying bacteria not
3	pseudomonas denitrifican.
4	**Reddy:** Well, I think this is not quite true. What is mentioned here (referring to
5	the reference text) is not pseudomonas?
6	**Leon:** Pseudomonas is like an organism and it is also a dentrifican which
7	converts ammonium compound. The answer is true.

We see from Protocol data 6 that both Benny and Reddy identified the use of different wordings in the test question and reference text as a major problem. Both participants unanimously indicated

that: "what is mentioned here (referring to the reference text) is not *pseudomonas*". But it was Benny who admitted, forthrightly, in line 1: "I must confess this question is quite confusing". The group, however, got the correct answer to the question after a third participant (Leon) reformulated the test question by using a simplified term to describe *pseudomonas*, as indicated in lines 6 to 7: "*Pseudomonas* is like an organism and it is also a *dentrifican*". Leon further explained the function of pseudomonas and denitrificans as organisms "which convert[s] ammonium compound". The extra-textual knowledge activated by Leon convinced the other participants to reason along with him on his choice of true as the correct answer to question 7 on whether pseudomonas and denitricans are synonyms.

In this section, we analysed the cognitive processes of participants as they respond to the different types of term variation. The analysis further described the strategies deployed by participants to surmount the challenges posed by term variation. The general conclusion drawn from this qualitative analysis is that, although term variation impacted negatively on participants in a number of the test questions, insights from the standpoint of legitimation code theory semantics showed that term variants can be leveraged to facilitate learning. The next section presents a synthesis of findings derived from the qualitative and quantitative findings.

6.7   Synthesis of quantitative and qualitative findings on the cognitive effects of term variation

In order to reach a valid conclusion on the cognitive effects of term variation, which was not possible by using either qualitative or quantitative results alone, we synthesised findings derived from both approaches in this section to determine whether the results derived from the two analytical methods are compatible or contradictory. To achieve this goal, we first present the mean

pass and failure rates of learners in the individual and group tests. The results will then be triangulated with the performance of learners per typological category of term variation to determine which category presented the most or least challenge to learners. The first part of the synthesis compares results based on the claim that term variation impedes learning while the second part compares results in order to illustrate that term variation is functional.

6.7.1   Synthesis of findings based on claims that term variation impedes learning

It can be recalled that the result of the Pearson product-moment correlation coefficient test indicated a negative correlation (StrongEng r = -0.7603, p <0.05) between language proficiency and achievement in the test on processing variant terminology. This finding is subjected to further analysis in order to determine whether it is compatible or at variance with conclusions derived from the qualitative findings. Table 32 presents the mean failure rate of Nigerian and South African learners in individual test scores and focused group discussion test scores. The table further indicates the mean pass and failure scores of learners in each of the typology of variation identified in chapter 5 of the study.

Table 32: Failure rate of Nigerian and South African learners in individual and group tests

Typology of variation	Individual test Mean failure rate (%)	Group test Mean failure rate (%)
Type 1 variation	39	42
Type 2 variation	15	35
Type 3 variation	55	60

We see from Table 32 that Type 3 variation had a high negative impact on learners in both the individual and group test scores of Nigerian and South African learners. In six of the ten questions, (i.e. questions 3, 5, 7, 8, 9 and 10), a mean average failure rate of learners in the task worded around Type 3 variation is fifty-five percent (55%) for the individual test and sixty percent (60%) for the group test. The second most challenging typology of variation in both the individual and

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group test is the Type 1 variation. A comparison of the mean of learners who did not perform well in both test formats indicates a mean failure rate of thirty-nine percent (39%) for the individual test and forty-two percent (42%) for the group test. Type 2 variation presents the least challenge to the learners as reflected in the low failure mean of fifteen percent (15%) in the individual test and thirty-five percent (35%) in the group test. We can deduce from the above synthesis that term variation has a nuisance value and that the three typologies of term variant identified in the study affects learners in different proportions. The most challenging typology to process (according to the synthesis) is Type 3 variation (or contamination of intersection) while the least challenging is Type 2 (or contamination of similarity). Let us now consider the second part of the synthesis, which compares the performance scores of individual and groups of learners to justify the claim that term variation is functional.

6.7.2 Synthesis of findings based on claims that term variation has functional value

The result of the synthesis in the preceding section showed that term variation impedes learning and that the typology that challenged learners most is Type 3 variation, or contamination of intersection. It was further shown that Type 2 (or contamination of similarity) is the least challenging of the three typologies. This section of the study compares findings derived from quantitative and qualitative analyses in order to verify whether the conclusion that term variation is functional should be confirmed or contradicted. Before the synthesis, let us recapitulate on the quantitative and qualitative findings that term variation is functional.

As stated earlier, results derived from the analysis of a null hypothesis indicated that science competence of learners is a correlate of achievement in a test on terminology processing, with a correlation of StrongSC $r = 0.25495$, $p > 0.05$. Qualitative analysis of the cognitive processes of

learners also showed that term variation is functional, particularly when a specialised term is substituted by a simplified synonym or when the meaning of a term is contextualised by exemplification. Table 33 presents the mean pass rate of Nigerian and South African learners in individual and focused group tests on terminology processing of variant terminology in life sciences textbooks.

Table 33: Pass rate of Nigerian and South African learners in individual and group tests

Typology of variation	Mean of individual test		Mean of group test	
	Pass rate (%)	Fail rate (%)	Pass rate (%)	Fail rate (%)
Type 1 variation	61	39	58	42
Type 2 variation	85	15	65	35
Type 3 variation	45	55	40	60

Reading Table 33 from the standpoint of the resource and nuisance values of term variants indicates that a high mean is associated most with Type 2 variation with a pass rate of eighty-five percent (85%) in the individual test and sixty-five percent (65%) in the focused group test. It is followed by Type 1 variation with sixty-one percent (61%) in the individual test and fifty-eight percent (58%) in the group test. Type 3 has the lowest mean pass rate in both tests administered with a pass rate of forty-five percent (45%) in the individual test and forty percent (40%) in the focused group test. We see from the above synthesis that both tests yielded the same result, i.e. the type of variation where learners performed optimally and that which posed the most challenge to learners was similar in both types of tests. In view of this, it is safe to conclude that term variation has both functional and nuisance value in life sciences textbooks for high school.

6.8 Summary of the chapter

This chapter discussed the effects of terminology variation on achievement based on insights from Gerzymisch-Arbogast's (1996) context-specific term model and Maton's (2013) legitimation code theory. We reported findings derived from two hypotheses that were subjected to empirical

analysis. The first hypothesis states the perception that proficiency of learners in English can predict performance in tasks involving the processing of terminology variation. However, a Pearson product-moment correlation coefficient value of r = -0.7603, $p < 0.05$ suggests that no correlation exists between language proficiency and the performance of learners in tasks processing variant terminology. The second hypothesis states that competence of students in science can predict performance in science tasks involving terminology variation. The analysis of the result indicated a Pearson product-moment correlation coefficient value of $r = 0.0205$, $p > 0.05$ upholding the notion that competence in science can predict achievement of learners in tasks on processing variant terminology.

By way of synthesis, we compared the performance of the participants involved in the study (i.e. those who wrote the test individually and those who wrote in groups) in respect of their mean averages. The result showed that no difference exists in the mean averages of participants involved in both type of tests. The outcome for the synthesis of the quantitative and qualitative data has proven to be useful because it has provided further insight into the effects of term variation and its implications for achievement in science. To conclude, the synthesis has revealed that participants find it easy to engage with the science content in the test questions when the knowledge encoded in terms are unpacked by other participants during deliberations on tasks. The second insight, as shown by the individual test written by participants, is that term variation has a nuisance value because it blocks learning and leads to poor comprehension (see Fang, 2006; Antia & Kamai, 2006; Snow, 2010).

CHAPTER SEVEN

TEACHING THE DYNAMICS OF TERMINOLOGY IN LIFE SCIENCES TEXTBOOKS FOR HIGH SCHOOL: PERSPECTIVES FROM TERMINOLOGY AND

SYSTEMIC FUNCTIONAL LINGUISTICS

7   Introduction

Chapter 5 of this study explored the nature and effects of term variation in Nigerian and South African life sciences textbooks based on insights from the context-specific term model proposed by Gerzymisch-Arbogast. Chapter 6 problematised term variation and determined its effects on learners with different levels of competence in English language and Science. This chapter draws on terminology (theory of term inconsistency), Lemke's construct of thematic pattern and systemic functional linguistics (transitivity analysis and thematic pattern analysis) to illustrate how content integrated terminology literacy can be applied to the teaching and learning of science.

Before proceeding with the description of how the proposed terminology literacy can be applied, it is important to present an overview of the achievement scores of Nigerian and South African participants in the ten-item test questions on processing variant terminology. This data is important because it will provide insight on the nature of the challenge each test question poses and also underscore the necessity of addressing the challenge. Table 34 presents an overview of the performance of the Nigerian participants.

Table 34: Performance of Nigerian learners according to teams (√ = correct answer; x = incorrect answer, %= percentage)

Question	dialogue Think-Aloud Protocol Teams										
	Arts-based school type						Science-based school type				
Topics	A	B	C	D	E	(%)	F	G	H	I	J	(%)
1 Nervous coordination	√	√	√	√	√	100	√	x	√	√	x	60
2 Nervous coordination	√	√	√	x	x	60	x	√	x	√	√	60
3 The cell	√	x	√	x	x	40	√	√	√	√	√	100
4 The cell	√	√	√	√	√	100	√	√	√	√	x	80
5 Plant nutrition	√	√	x	√	√	80	√	√	x	√	√	80
6 Plant nutrition	x	√	√	√	√	80	√	√	√	√	√	100
7 Nitrogen cycle	x	√	x	x	√	40	x	√	x	√	x	40
8 Nitrogen cycle	√	√	x	√	√	80	x	√	x	√	√	60
9 Respiration	x	x	√	x	x	20	√	√	√	√	√	100
10 Respiration	x	√	x	x	x	20	x	√	x	√	x	40
Total	06	08	06	05	06	50	06	09	06	10	06	70

As depicted in Table 34, there are only two instances, i.e. questions 1 and 4, where all the participants gave accurate answers to the test questions among the Nigerian participants recruited from the arts-based secondary schools. Similarly, participants recruited from the science secondary school also recorded one hundred percent in questions 3, 6 and 9. The performance of learners across both school types, however, showed the lowest scores, twenty percent (20%), recorded for questions 9 and 10 among Nigerian learners recruited from arts secondary school and forty (40%) recorded for questions 7 and 10 among learners from the science secondary school. Table 35 presents the mean failure rate of the Nigerian learners.

Table 35: Means of the performance of Nigerian learners from arts and science schools

Test questions	Mean failure rate of Nigerian learners	
	Arts-based school type (%)	Science-based school type (%)
1–10	50	30

Performance of Nigerian learners as indicated in Table 35 indicates that fifty percent (50%) of Nigerian learners from the arts school had problems processing term variants while a thirty percent (30%) mean was recorded for learners from the science school. An overview of the performance of the South African learners is presented in Table 36.

Table 36: Performance of South African learners according to teams (√ = correct answer; x = incorrect answer, %= percentage)

Question	dialogue Think-Aloud Protocol Teams											
	Arts-based school type						Science-based school type					
Topics	A	B	C	D	E	(%)	F	G	H	I	J	(%)
1 Nervous coordination	√	√	√	√	√	100	√	√	x	√	√	80
2 Nervous coordination	√	√	√	√	√	100	√	√	x	x	√	60
3 The cell	x	√	√	x	x	40	√	x	x	√	√	60
4 The cell	x	x	x	x	√	20	√	√	√	x	x	60
5 Nitrogen cycle	x	√	x	x	√	40	x	√	√	x	x	40
6 Nitrogen cycle	x	x	x	x	x	00	x	x	x	x	x	00
7 Blood circulation	√	x	√	x	√	60	√	√	√	x	√	80
8 Blood circulation	x	√	√	√	√	80	√	√	x	√	√	80
9 Water transport	√	√	√	x	x	60	√	x	√	√	√	80
10 Water transport	√	√	√	x	x	60	x	x	x	x	√	20
Total	05	07	08	03	06	51	07	06	04	06	07	60

In respect of the South African participants from the arts high school, results presented in Table 36 indicate that only questions 1 and 2 recorded a one hundred percent (100%) success rate. The remaining questions recorded a range of scores from zero (00%) in question 6 to eighty percent (80%) in question 8. For South African learners from a special science or Dinaledi school, the highest performance rate is eighty percent (80%), recorded for questions 1, 7, 8 and 9. Like learners from the special arts school, zero percent (00%) was recorded in question 6 among participants from the special science school recruited for the study. Table 37 presents the mean failure rate of South African participants.

Table 37: Means of the performance of South African learners from arts and science schools

Test question	Mean failure rate of South African learners	
	Arts-based school type (%)	Science-based school type (%)
1–10	49	40

As depicted in Table 37, the mean failure rate of learners among the South African learners from an arts curriculum based school is forty-nine percent (49%) while those from the school where a science curriculum is taught is forty percent (40%). In view of the foregoing, we can see that term variation had negative effects on learners in different proportions across regions and school types. The mixed outcomes observed among Nigerian and South African learners suggest that term variation might have been a source of problems for both categories of learner. The high performance rate recorded in certain questions need to be interpreted cautiously because this might be as a result of a fluke. The next section illustrates how participants who did not do well in the test administered could have deployed transitivity analysis in order to identify term variation. It also illustrates how learners could have used knowledge of thematic pattern analysis to provide a

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convincing rationale for their answers.

7.1 Transitivity analysis of clauses in Nigerian and South African reference texts and the test questions

This section presents a transitivity analysis of the test questions and the reference texts given to the Nigerian and South African participants in the study. The aim of the analysis is to show how the participants might have avoided getting the wrong answer to the question by exploring a compensatory text resource called thematic pattern. Forty (40) clauses comprising twenty (20) from each country were analysed to determine how the test questions and the reference texts varied in their use of terms. A comprehensive transitivity analysis on each set (i.e. a test question and a reference text) can be found in Appendix 1. Meanwhile, we present transitivity analysis and commentary on one Nigerian test question and reference text (on the sensory neurone) and one South African test question and reference text (on diffusion).

For the question on the sensory neurone, the text given to the participants is derived from *New Biology* while the question is based on a text excerpt on sensory neurones in *College Biology*. The question is worded to determine whether the participants can identify the relationship of synonymy involving the use of *sensory cells* in the Place alpha slot and *central nervous system* in the Place beta slot of the reference text. The correct answer to question 1 is "true". As Table 33 indicates, for question 1, Nigerian learners from the arts secondary school scored one hundred percent (100%) while their counterparts from the science secondary school had a pass rate of sixty percent (60%). Table 38 presents the transitivity analysis of the clauses in question 1 and of reference text 1.

Table 38: Transitivity analysis of Reference text 1 and Test question 1 on the sensory neurone

Function: Text source	Actor	Process	Goal	Circumstances: Place	
				Place alpha	Place beta
Text 1:	sensory neurone nervous	transmits	sensory impulses	from receptors	to the central system
Text 2:	sensory neurone	transmits	nerve impulse	from sensory cells	to the brain & spinal cord

Note: Text 1: Reference text 1; Text 2: Test question.

A transitivity analysis of the clauses in Text 1 and Text 2 as illustrated in Table 38 shows that both text configurations make use of a Material Process verb *transmits* which encodes a Participant functioning as Actor, also consistently described as *sensory neurone*. The Goal constituent is referred to as *sensory impulses* in the Reference text and *nerve impulses* in the Test question. The Circumstance slot is also realised by two variants, namely: *receptors* in the Reference text and *sensory cells* in the Test question for the description of the term in the Place alpha slot. Term variation can also be observed in the Place beta constituent where *central nervous system* is used in the Reference and *brain and spinal cord* is used in the Test question.

But despite the use of these term variants, we can see that both text sources activate a shared thematic pattern construing a thing designated by (a term Y) (which sends) SOMETHING (called X) (from one) LOCATION (to another) LOCATION. This kind of reasoning is what learners need to deploy, in order to comprehend their science textbooks and to provide justification for their choice of answers to test questions. Let us further analyse the clauses in the test question and reference text in question 5.

The reference text given to participants in order to answer question 5 on diffusion is derived from *Study and Master Life Sciences* while the Test question is derived from *Oxford Successful Life Sciences*. The rationale for the question is to find out whether the participants can establish a relationship between the doublet *molecules of substances (solid, liquid and gas)* and its variant *water molecules*. We see from the summary of results presented in Table 35 on the performance of South African learners, that sixty percent (60%) of learners across school types performed poorly on this question, suggesting that participants perceived this question to be challenging. Table 39 presents a transitivity analysis of the test question and the reference text. The table is followed by a commentary describing how transitivity and thematic pattern analysis would be used to identify and respond to the term variation associated with this question.

Table 39: Transitivity analysis of Reference text 5 and Test question 5 on diffusion

| Function: Token | Process | Goal | Value: Place | |
Text source			Place alpha	Place beta
Text 1: diffusion	is movement	of molecules (solid, liquid and gas)	from region of high concentration	to region of low concentration
Text 2: diffusion	is movement	of water particles	from an area of high concentration	to an area of low concentration

Note: Text 1: Test question 5; Text 2: Reference text 5

The clause in the reference text consulted by the participants makes use of a Relational (identifying) Process where the verbal group, *movement* encodes a Token, *diffusion*; a Goal which is described as *water particles* and a Value or that which gives identification (Ravelli, 2000) described as *area of high concentration* and area *of low concentration* for the Place alpha and Place beta constituents respectively. The test question also makes use of a Relational (identifying) Process where the verbal group, *movement* identifies the Token, *diffusion*. The terms in the Process

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and the Goal slots, are described as *movement* and *molecules (solid, liquid and gas)* respectively. For the Circumstance constituents, the Place alpha and beta are described as *region of high concentration* and *region of low concentration.*

As transitivity analysis in Table 39 indicates, both texts construe the same scientific reality or ideational content. The major difference between the reference text and the test question, however, involves the use of the term variants in the Goal slot, which are realised by a superordinate term described as *molecules (solid, liquid and gas)* in the test question and a subordinate term realised as *water particles* in the reference text. Meanwhile, we can see that the thematic patterns in both text configurations are similar because they all specify that: SUBSTANCES (are being moved by) THING from one PLACE (to another) PLACE. This inference can be used as a basis for the choice of an answer to a test question and for providing a justified rationale for the choice. It can also be used for "talking science", by which is meant the ability to communicate scientific knowledge (Lemke, 1990). Let us now turn to the last example (on osmosis).

For question 3 on osmosis, the text given to participants to consult is derived from *Study and Master Life Sciences* while the question is also based on osmosis as described in *Oxford Successful Life Sciences*. The rationale for the question is to find out if participants can identify *diffusion* in the test question as a term variant for *movement* in the reference text. As Table 35 indicates, for the individual scores, sixty per cent (60%) of learners who failed the test question are from the arts school while a forty per cent (40%) failure rate was recorded at the science school. This implies that more than half of the learners across the school types had a problem in identifying and resolving the challenge posed by question 3. Table 40 presents the transitivity analysis of

Reference text 3 and Test question 3 which learners should have done in order to excel on tasks involving the processing of variant terminology.

Table 40: Transitivity analysis of Reference text 3 and Test question 3 on osmosis

Function: Token	Process	Goal	Value: Place	
Text			Place alpha	Place beta
Text 1: osmosis	is diffusion	of water molecules	from region of low concentration	to a region of high concentration
Text 2: osmosis	is movement	of water molecules	from an area of high water potential	to an area of low water potential

Note: Text 1: Reference text 3; Text 2: Test question 3

From the ideational perspective of meaning or how reality is construed, the Reference text consulted by the participants makes use of a Relational (identifying) Process where the verbal group, *diffusion* identifies a Token (i.e. that which is being identified) *osmosis*; a Goal which is described as, *water molecules* and a Value referred to as *region of low concentration* in the Place alpha constituents and *region of high concentration* for the Place beta slot. The test question makes use of a Relational (identifying) Process where the verbal group this time is *movement*, which also identifies a Token, *osmosis*. The Goal is also described as *water molecules* while the Place alpha and beta are described differently, as *area of high water potential* and *area of low water potential,* respectively. Despite the fact that both text configurations use a range of variants to describe osmosis, they both activate the same underlying grammatical relation specifying that: SUBSTANCES (are moved by a) THING (from one) PLACE (to another) PLACE. This is the type of inference participants could have used to surmount the challenge posed by synonymy in the text question. It could have also been used as a convincing rationale for the choice of "true" as the

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correct answer, which is lacking in the participants' responses as observed in Protocol data 1 by Baya and in Protocol data 4 by Adler.

The aim of this section of the study was to describe the diagnostic potentials of transitivity analysis and to further show that thematic pattern analysis is a useful heuristic for responding to term variation. We argued in this section that the knowledge of these metalinguistics skills is more important to high school learners than ability to speak and write in correct English. This claim is also expressed by Lemke (1990) in his account of talking science as more than just cramming the formula of chemical equations or parroting back the words of teachers. This view is in consistent with English (1998:58) where it was emphasised that knowledge of "causes and effects of language and other forms of grammatical relations" are important for science learners. We therefore conclude that in order to process specialised texts effectively and to provide convincing rationales for answers to test questions, learners need the metalinguistic skills described above. The next section illustrates how these skills can be applied in a pedagogic context.

7.2 Responding to term variation through content integrated terminology literacy: overview of the proposed pedagogy and application

The previous section of the chapter illustrates how transitivity and thematic pattern analyses can serve as frameworks for identifying and responding to term variation in high school life sciences textbooks. Forty clauses derived from Nigerian and South African test questions and reference texts that were administered to learners were analysed in order to show how the different text configurations activate the same grammatical relation despite their varied use of terminology. The topics that the extracted clauses dealt with included the description of sensory neurones, diffusion and osmosis. This section describes, by means of a lesson plan, how the content integrated

terminology literacy outlined in Antia & Kamai (2016) can be applied by teachers to address comprehension challenges resulting from term variation.

The proposed framework has three major stages: the first stage, on sensitisation to terminology in knowledge and text; the second stage, on sensitisation to variant terminology and a third stage, which describes confirmatory procedures for determining terminological equivalence (Antia & Kamai, 2016). The first stage is aimed at sensitising learners to the nature and use of terminology in knowledge and text. The second stage builds on the first stage by drawing the attention of learners to the reality and functions of variant terminology. The third illustrates the diagnostic potentials of transitivity analysis to address challenges that may arise from the use of variant terminology.

The topic we shall use in illustrating the three stages of the terminology literacy is the nitrogen cycle. The learning outcomes of the lesson are to illustrate to learners how to use transitivity analysis to identify term variation and to illustrate how learners can apply knowledge of thematic pattern to respond to term variation. At the end of the lesson, learners are expected to demonstrate the application of these metalinguistic skills by carrying out some exercises on the processing of variant terminology. The lesson is suited for grade 12 learners and is expected to last for not more than 40 minutes.

The instructional materials/teaching aids for the lesson include text excerpts and graphics derived from textbooks recommended for use in Nigerian and South African high schools. A second important teaching aid is the transitivity table, which will be used to map the clauses describing

the nitrogen cycle in the different text sources. The table also specifies the grammatical functions and classes of words, using the conventions of systemic functional linguistics. The next section describes how the three stages of the proposed content integrated terminology literacy can be implemented in a pedagogic context.

7.3   Application of the content integrated framework for terminology literacy in the science classroom

This section designs a forty-minute lesson plan and describes how the three stages of the proposed content integrated terminology literacy can be implemented in a pedagogic context. The three stages of the terminology literacy framework are described alongside the sub-moves associated with each stage. The teacher and learner activities for each stage and micro-move are also described as specified in genre pedagogy (Rose & Acevedo, 2006). An overview of the three stages and their micro-moves are described below.

7.4   Content integrated terminology literacy: theoretical underpinnings and pedagogic procedures

As stated from the outset, there is dearth of research on a detailed pedagogic procedure for processing variant terminology in science textbooks (Bradbeer et al., 1976; Evans, 1976; Yager, 1983; Letsoalo, 1996; Antia & Kamai, 2006). To address this gap, content integrated terminology literacy was therefore proposed in Antia & Kamai (2016) after a decade of research on the dynamics of terminology in biology textbooks. The pedagogic framework is an outcome of action research that is motivated by the Halladayan notion of a language- based theory of learning (Halliday, 1993). It is an eclectic framework which draws not only from systemic functional linguistics but also genre pedagogy (Rose, 2005; Rose & Martin, 2012; Rose & Acevedo, 2006) and terminology theory (Gerzymisch-Arbogast, 1996 & 2008). Like Content and Language

Integrated Learning (Graddol, 2006), it is specifically developed to scaffold content learning and language development across subjects in the curriculum simultaneously.

The pedagogic literacy model has three major components (also stages). The first is aimed at sensitising learners to the nature and use of terminology in knowledge and text. The second stage builds on the first stage by drawing the attention of learners to the reality and functions of variant terminology. The third illustrates the diagnostic potentials of transitivity analysis to address challenges that may arise from the use of variant terminology (see Antia & Kamai, 2016). The proposed pedagogy adapts the deconstruction and detailed stages of genre pedagogy (see Rose, 2005; Rose & Acevedo, 2006; Rose and Martin; 2012). The next section enacts the three stages of the content integrated terminology literacy showing how learners can identify and respond to term variation in their engagement with written science.

7.5 Pedagogic application of content integrated terminology literacy

We design a lesson plan based on content integrated terminology literacy and illustrate how it can serve as a framework for scaffolding teaching and learning that focuses on language and literacy. We assume that exposing learners to the three stages of the framework can help them surmount comprehension challenges resulting from the use of term variants in science textbooks. As a syllabus reference for the lesson of about forty minutes, we choose the nitrogen cycle as the topic to be taught. This topic would be addressed by students in the final year of secondary schooling in Nigeria or South Africa. Three relevant textbook excerpts, with similar ideational content, serve as a basis for the lesson. The objectives of the lesson are to sensitise students on the one hand, to the importance of terminology and the problem term variation may sometimes pose and, on the other hand, to develop their competence in identifying thematic patterns and using these patterns

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to resolve problems associated with term variation. Table 41 presents the ancillary part of a lesson plan specifying the grade for which the lesson is meant, the topic of the lesson, the language focus of the lesson, the aim and objectives of the lesson and the requisite materials and time needed to implement the three stages of content integrated terminology literacy.

Table 41: Lesson aim, objectives and materials needed to enact the three stages of the content integrated terminology literacy

Year/Stage: Senior Secondary School Level 3

Topic: Nitrogen cycle

Language focus: Analysis of the dynamics of terms in biology textbooks

Instructional aids: Text excerpts on the Nitrogen cycle

Behavioural objectives:

By the end of the lesson, learners should be able to:

(a) identify term variants in science textbooks using transitivity tables and

(b) apply thematic pattern analysis to establish a relationship between term variants

Duration: Forty minutes

The next section explains what constitutes each stage of the proposed pedagogy, the teacher and learner activities associated with each stage and the associated expected learning outcomes.

7.6   Stages of the proposed pedagogy

7.6.1   Stage 1: Sensitisation to terminology in knowledge and text

The sensitisation stage of the content integrated terminology literacy is an adaptation of the deconstruction stage in genre pedagogy. At this stage of the lesson, the teacher sets the context (also called "prepare" in genre pedagogy) by providing the requisite background knowledge learners need to properly comprehend the text (Rose & Acevedo, 2006). One way of achieving

this is through sensitising learners to the dynamics of terminology in specialised text, as illustrated in Micro-move 1.

7.6.1.1 *Stage 1, Micro-move 1: identification of terms and non-terms*

This move invites learners to reflect on the importance of terminology in specialised texts. Here, the teacher and the learners jointly create two text configurations. In the first text, all the terms are omitted leaving only the non-terms. In the second configuration however, it is the non-terms that are omitted. Textboxes 3 and 4 illustrate sample texts that can be used in Micro-Move 1.

Some [1] like [2] which are found in the [3] of [4] are used to form [5], [6] and [7] which they share with the [8].

Textbox 3: Sample text with terms omitted for sensitisation on the importance of terms in specialised text

_____ 1 micro-organisms _____ 2 rhizobium _____ 3 root nodules ------ leguminous plants

_____ 5 gaseous nitrogen, 6 amino-compounds _____ 7proteins _____ 8 host plants.

Textbox 4: Sample texts with non-terms omitted for sensitisation on the importance of terms in specialised texts

7.6.2 Stage 2: Sensitisation to variant terminology in specialised text

In this stage of the lesson, learners' attention is drawn to the reality and dynamics of terminology in specialised texts. In other words, that although terms are the control "centres" (de Beaugrande, 1997) or mechanisms for ensuring determinacy in specialised text, they are also prone to variation. At the end of this stage learners are expected to recognise the fact that the use of terms in specialised texts are not always as precise as may be specified in a system such as a glossary or a

dictionary. To achieve this learning outcome, learners are given a new text on nitrogen fixation but this time from a different text source that uses a somewhat variant set of terminology (see Textbox 5).

7.6.2.1   *Stage 2, Micro-move 1: literacy in identifying variant terminology*

Micro-move 1 in stage 2 of the proposed pedagogy equips learners with the requisite metalinguistic strategies for identifying variant terminology in texts. During this phase of the lesson, learners will be asked to assign identical numbers to the terms in the new text which they consider to be equivalent to the terms in the earlier text, as illustrated in Textbox 5 (note the bolded parts of the text).

The species of [1] **bacteria of *Rhizobium*** such as [2] ***R. leguminosarium*** have symbiotic association with [3] **roots of some leguminous plants** such as groundnuts, beans and crotalaria. These symbiotic bacteria enter the root hair walls of the legumes and multiply thus causing swellings or nodules in the infected cells. They absorb the [4] **atmospheric nitrogen** in the soil and build up into [5] **nitrates** which the roots of the [6] **plants** absorb to form [7] **proteins.**

Textbox 5: A sample text for pedagogy of literacy in variant terminology

A comparison of the use of terms in the three text configurations, i.e. Textboxes 3, 4 and 5 will show that despite the fact that the wordings used across the three text configurations vary, the scientific reality or ideational content in the three texts is similar (because of the similar account on ammonia being transformed to nitrite in both texts). Learners can be asked to verify this by comparing the use of terms in texts 3 and 5. The analysis would show that the term *micro-organism* is used in Textbox 4 while *bacteria of rhizobium* is used in Textbox 5; *gaseous nitrogen* is used in

Textbox 3 while *atmospheric nitrogen* is used in Textbox 5 and *amino- compounds* is used in Textbox 3 while *nitrates* is used in Textbox 5. Now that leaners have been shown that the use of terms in some contexts is not always precise or determinate, the lesson can proceed to the third stage of the proposed pedagogy.

7.6.3 Stage 3: Confirmatory procedures for establishing relationships between term variants

We illustrated in the first and second stages of the lesson how learners' attention can be drawn to the dynamics of terminology in specialised text and how learners can identify and respond to term variation. This stage of the lesson is aimed at equipping learners with metalinguistic skills for confirming conceptual equivalence between term variants (Antia & Kamai, 2016). The stage therefore requires the teacher and the learners to further analyse the clauses the term variants appear (in Textboxes 3 and 5) by doing transitivity and thematic pattern analyses.

7.6.3.1 *Stage 3, Micro-move 1: application of thematic pattern analysis to establish relationships between term variants*

Micro-move 1 in stage 3 illustrates a confirmatory procedure for establishing relationships between term variants, in which the teacher and learners map the clauses of two text configurations on a transitivity table. The aim of this joint activity is to confirm whether the meanings construed in both clauses are similar despite the use of variant terms in the test question (Text 1) and the reference text (Text 2). Table 41 exemplifies how transitivity analysis can be used as a further confirmatory framework for establishing similarity of meaning in clauses that use variant terminology.

Table 42: Clauses with the same thematic pattern but showing some differences in wording

Function	Actor	Process Material	Goal	Circumstance	
Class	Nominal	Verb	Nom; group alpha	Prep	Nom; group beta
Text 1	Nitrifying bacteria	converts	organic nitrogenous compounds	to	inorganic nitrogenous compounds
Text 2	Nitrifying bacteria	converts	ammonium compounds	to	nitrite and nitrate

The analysis of both clauses as illustrated in Table 41 would enable learners to see that both text configurations have a Material Process verb *converts* which encode an Actor realised as *nitrifying bacteria*. But unlike the Actor and Process slots, the Nominal group alpha constituent in the clauses of both text sources are described as *organic nitrogenous compounds* in text 1 and *ammonium compounds* in text 2. Similarly, term variation manifests in the Nominal group beta slot as *inorganic nitrogenous compounds* in text 1 and as *nitrite and nitrate* in the Nominal group beta slot of text 2. Despite the differences in wording observed in both text configurations, one cannot avoid noticing that both text sources have the same thematic pattern describing causality. In other words, both clauses describe an entity called (X) which transforms a thing designated as (Y) to form another entity called (Z).

This section of the chapter illustrated a lesson plan that is designed for implementation in a content integrated terminology literacy context. The lesson plan is underpinned by theoretically informed language and text analytical skills which are lacking in learners' protocol data as discussed in chapter six of the study. Learners' inability to apply these metalinguistic skills might explain why some of them did not do well in some of the test questions. It might also explain why those who got the correct answers could not explain their rationale for the choice of the correct answer. On the whole, the proposed content integrated terminology framework might do much to improve

learners' performance in Life Sciences, it however needs to be tested in order to determine its efficacy and potentials for regular classroom application.

7.7   Summary and conclusion of the chapter
This chapter drew insights from terminology (theory of term inconsistency), Lemke's construct of thematic pattern and systemic functional linguistics (transitivity analysis and thematic pattern analysis) in order to illustrate how content integrated terminology literacy can be applied to the teaching and learning of Life Sciences in the high school. An overview of the achievement scores of Nigerian and South African participants in the ten-item test questions on processing variant terminology provides contextual evidence of the need for this. After discussing the performance of learners in the test administered, test questions where term variation impacted negatively on learners were identified. The clauses in the test questions and reference texts were then analysed to illustrate how learners' knowledge of transitivity and thematic pattern analyses would have made it easier for them to identify and respond to the challenges posed by term variation.

The chapter further proposed a framework for pedagogy of literacy in variant terminology and described the various components of the framework**.** This was followed by a section that outlined how the proposed framework can be applied in the life sciences classroom, using text excerpts on nitrogen cycle–as example. The next chapter summarises the major findings from the study, presents the conclusions derived from the quantitative and qualitative results and recommends directions for further research.

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8   Introduction

The aim of this chapter is to provide a summary of the major findings of the study. The chapter also outlines the major conclusions drawn from the outcomes of qualitative and quantitative analyses and proffers recommendations and directions for future research. As a prelude to recounting the major findings and the conclusion of the study, let us present an overview of the aim and the methodology adopted.

8.1   Overview of the study and the methodology adopted

This study examined the dynamics and the effects of term variation in Nigerian and South African high school textbooks on life sciences, based on a multi-theoretic framework. The components of the framework comprise the context-specific term model proposed by Gerzymisch-Arbogast (1996 & 2008), Lemke's (1990) construct of thematic pattern and the legitimation code theory semantics proposed by Karl Maton (2013). As was stated from the outset, the study was motivated by the dearth of research on the dynamics of terminology variation in English-language school science textbooks. Another motivation for the study was the high rate of underachievement in science and the consequent high drop-out rate and science avoidance in sub-Saharan Africa (TIMSS, 2011; PISA Report, 2015; SACMEQ Report, 2015).

As a way of addressing these gaps, the study formulated seven research questions and three research hypotheses, with the aim of providing a nuanced perspective on the dynamics of terminology in high school life sciences textbooks and its effects on the performance of Nigerian

and South African learners. The research questions were as follows: (1) what are the types of term variant in Nigerian and South African life sciences textbooks for high school? (2) how evenly widespread are term variants within and across identified types in Nigerian and South African life sciences textbooks? (3) how are learners with different proficiency levels in English affected by term variants? (4) how are learners with different competence levels in science affected by term variants? (5) is there a correlation between the performance of Nigerian and South African learners in tasks on terminology processing? (6) to what extent can patterns of cognitive processing of terminology variation observed in learners be explained by Gerzymisch-Arbogast's system-text theory, Lemke's thematic pattern and Maton's legitimation code theory? and (7) what methods of teaching can be developed to address the issue of term variation observed in life sciences textbooks?

In order to address the research questions on the effects of term variation on the performance of Nigerian and South African learners, three research hypotheses were also formulated to determine the correlation between the performance of learners and their achievement in tasks on processing variant terminology. The research hypotheses formulated included the following:

$H0_1$: there is no correlation between the performance on the task worded around term variation and the learners' proficiency in English language.

$H0_2$: there is no correlation between the performance on the task worded around term variation and the learners' competence in science.

$H0_3$: there will be a significant difference between the performance of Nigerian and South African learners in tasks involving terminology variation.

To effectively provide answers to the above research questions, we adopted a mixed-method research design which combines qualitative and quantitative analytical methods. The qualitative method involves the use of interpretive thematic content analysis (ITCA) while the quantitative method relates to the use of inferential test statistical tools (i.e. Pearson product-moment correlation coefficient and Fischer Exact tests). The answers to the research questions and the results of the three hypotheses formulated in the introductory chapter of the study are summed up in the next section and presented as the major findings of the study.

8.2   Summary of the major findings of the study

The results derived from the multi-theoretic analyses of the dynamics and the effects of term variation in Nigerian and South African life sciences textbooks are chapter specific. In other words, each of the findings is discussed in a separate chapter so that results on the dynamics of and the arguments on its effects flow logically as the study unfolds. Consequently, chapter 5 discussed the study findings on the typology and distributions of term variation in Nigerian and South African life sciences textbooks. Chapter 6 examined the effects of term variation on the performance of Nigerian and South African learners, based on quantitative and qualitative data and in turn synthesised the findings. Chapter 7 of the study proposed and illustrated a content integrated framework for terminology literacy. This section presents a summary of the major findings of the study. It is structured so that each finding is presented as a response to the research question or hypothesis formulated.

8.2.1   Research question 1: what are the types of term variants in Nigerian and South African life sciences textbooks for high school?

Research question 1 was formulated to foster the development of a typology of term variants and their manifestations in Nigerian and South African life sciences textbooks for high school. The

analysis was underpinned by Gerzymisch-Arbogast's (1996 & 2008) context-specific term model. The results of the analysis showed that the term variants in the Nigerian and South African textbooks could be categorised according to the typology proposed by Gerzymisch-Arbogast (1996 & 2008). Consequently, a slightly modified typology was developed which included: Type 1 variation, Type 2 variation and Type 3 variation. These categories correspond to contamination of similarity, inclusion and contamination of intersection as proposed by Gerzymisch-Arbogast (1996 & 2008).

Type 1 variation results when two synonyms, e.g. *water* and *solvent*, are used interchangeably to refer to any tasteless, odourless transparent fluid (Machery & Sappela, 2010). Type 2 variation manifests when a hypernym or superordinate term, e.g. *bacteria* is used interchangeably to represent a hyponym or subordinate term, e.g. *azotobacter*. A further typology of term variants identified in the Nigerian and South African textbooks is Type 3 which manifests when two terms are used interchangeably so as to represent concepts which intersect at the system level. It is realised linguistically for instance when a term such as *central nervous system*, which comprises brain and spinal cord, is used to imply a synonym such as *brain*.

8.2.2 Research question 2: how evenly widespread are term variants within and across identified types in Nigerian and South African life sciences textbooks?

Research question 2 is formulated to determine the frequency of the typologies of term variations (Types 1–3) that were identified in the Nigerian and South African life sciences textbooks. Results of the analysis showed that the distributions of the different variation types co-occur with equal frequency in both Nigerian and South African corpora but vary in the manifestations across the constituents of the clauses analysed. From the standpoint of the proportion of term variants per

typological categories, the results showed that Type 1 variation or contamination of similarity has the most frequent occurrence in both corpora, although the South African corpus had the highest frequency, i.e. seventy-nine (79), representing ninety-three percent (93%) compared to sixty-three (63) occurrences or ninety-one percent (91%) in the Nigerian corpus. The next in rank in respect of frequency is Type 2 variation, which occurred more often in the Nigerian corpus, with a frequency of four (4) representing six percent (6%).The typology with the least frequency is Type 3 variation, which had a frequency of (3) representing (9 %) in both the Nigerian and South African corpora.

Results on the manifestations of term variants in the clause constituents of Nigerian and South African life sciences textbooks also revealed an uneven distribution in the clause constituents of Nigerian and South African life sciences textbooks. Results of the analysis showed that the Circumstances slot had the highest frequency in the Nigerian corpus while the Participant slot had the highest in the South African corpus. In both Nigerian and South African corpora however, the Process slot had the lowest frequency. One possible reason for the low frequency of term variants in the Process constituent might be that, unlike other functional categories (i.e. Participants and Circumstances slots), which are nominal, adjectival or adverbial groups, the Process slot involves only verbs.

8.2.3 Research question 3: how are learners with different proficiency levels in English affected by term variants?

Research question 3 subjected to empirical analysis the claim by language educationists, (Maier & Schweiger, 1993; Audu, 2005; Fakeye & Ogunsiji, 2009) who argued that achievement in science can be attributed to the proficiency of learners in English language. In order to verify this

claim, we proposed a null hypothesis and tested it, using a Pearson product-moment coefficient correlation test. The null hypothesis states that:

H0$_1$: there is no correlation between the performance on the task worded around term variation and the learners' proficiency in English language.

The results of the Pearson product-moment coefficient correlation test indicated a negative significant correlation between learners' proficiency in English language and their achievement in the test on processing variant terminology, with a coefficient of StrongEngr $=$ -0.7603, $p>0.05$. This is interpreted to mean that the perceived competence of learners in English language cannot predict performance in science tasks on identifying and resolving terminology variation. The finding that learners' language proficiency cannot predict achievement in the test administered contradicts the results reported in Audu (2005), Maier and Schweiger (1993) and Fakeye and Ogunsiji (2009) but adds further empirical evidence to a body of research which associates academic achievement with cognitive academic language proficiency (CALP) rather than language proficiency as narrowly defined in language education research (see Cummins, 2000).

8.2.4   Research question 4: how are learners with different competence levels in science affected by term variants?

Research question 4 also used a Pearson product-moment correlation coefficient test to examine whether the competence of learners in science as determined by previous assessment scores can be a correlate of achievement in tasks on processing variant terminology in life sciences textbooks for high school. To this effect, a null hypothesis was formulated thus:

H0$_2$: there is no correlation between the performance on the task worded around term variation and the learners' competence in science.

Results of the Pearson product-moment coefficient correlation test indicated a significant correlation between the science competence of learners and their achievement in tasks on processing term variation, with a Pearson correlation coefficient of StrongScr $_=$ -0.9469, p>0.05 demonstrating that a significant relationship exists between the strength of learners in science and achievement in the test on processing variant terminology. This finding is consistent with the view of Winterton et al. (2005) who argued that the crisis in science literacy can be addressed, not by improving language proficiency, but by a broader conception of literacy that encompasses general and specific skills ranging from the ability to use mental models in different settings (Lijnse, 1990) to the ability to detach content from contexts (Kauertz et. al, 2012) and the ability to identify different kinds of knowledge that are linked by functional relations (see Resnick & Ford, 2012; Maton, 2013). This contradicts, however, the findings reported in Audu (2005), Maier and Schweiger (1993) and Fakeye and Ogunsiji (2009), where language proficiency is viewed as a factor of achievement in science.

8.2.5 Research question 5: Is there a correlation between the performance of Nigerian and South African learners in tasks on processing variant terms?

Research question 5 was set to determine whether there is a correlation between the performance of Nigerian and South African learners in the test administered on processing variant terminology. A null hypothesis was formulated and tested using a chi-square test statistical tool. The hypothesis formulated states that:

H0₃: there will be no significant difference in the performance of Nigerian and South African learners in a test on processing variant terminology.

Results of the chi-square test indicated a coefficient ($x^2 = 0.474486$, *p>0.05*) indicating that there is no significant difference between the performance of South African and Nigerian learners in the test on terminology processing as a task in learning science. Based on this inference, the proposed null hypothesis that no relationship between the performance of the Nigerian and South African learners in the test administered was upheld. This finding contradicts the results reported in Atebe and Schaffer (2010) who showed that Nigerian learners had a weaker understanding of basic geometry terminology than their South African counterparts. It also contradicts the results reported in the World Economic Forum Report 2010-2011 where South Africa is positioned below Nigeria in the international benchmark average for science achievement.

8.2.6 Research question 6: Can patterns of cognitive processing of terminology variation observed in learners' protocol data be explained theoretically?

Research question 6 sought to determine whether patterns of cognitive processing of term variants observed in participants' protocol data can be explained by the three theories that underpinned the study. To answer this question, the protocol data of learners were qualitatively analysed using an interpretive thematic content analytical technique (ITCA). The results of the analysis were then interpreted based on insights from Gerzymisch-Arbogast system-text theory, Lemke's thematic pattern and Maton's legitimation code theory. The findings related to research question 6 are presented in three parts to conform to the three theories that underpinned the study.

8.2.6.1 Research question 6a

Results of the analysis of participants' cognitive processing of term variants showed that learners were challenged by the different typologies of term variant identified by Gerzymisch-Arbogast (1996; 2008). This challenge manifested when a term for a concept in the reference text is substituted with a synonym (i.e. Type 1 variation) in the test question as exemplified in Protocol data 11: *"Aa aah* (meaning no), *I must confess that this question is quite confusing. The test question says hypertonic to hypotonic while here* (referring to the reference text) … *it says dilute solution to concentrated solution"*. In Protocol data 12, learners were deliberating on the process of nervous coordination; participants got wrong answers and reckoned that: *"According to what the reference text says, it (referring to internuncial neurone) links the brain with the effectors, it* does not say *sensory organs"*. Unlike in situations where Type 1 variation is easily identified in the case of *effector* and *sensory organs*, learners could not describe the nature of the challenge posed by Type 2 and Type 3 variations as depicted in the following Protocol data 13: "I think it's false. Yeah it's false … because diffusion deals with gases not solid and liquid".

8.2.6.2 Research question 6b

Results of the qualitative analysis of the dialogue Think-Aloud Protocol further lends credence to the Lemke's view that learning science is not just the "mastery of vocabulary or even recital of scientific definition but it is rather knowledge of network of relationships among scientific concepts and knowledge of how language is used in a field or context" (Lemke, 1990: 13). The tendency for participants to merely "parrot" or read relevant reference text sections as justifications for the choice of answers was observed in Hugo's protocol data on the Krebs cycle: "The answer is false because they say here that (reading the reference text aloud) *Krebs cycle is formation of citric acid when pyruvic acid is converted to acetyl co-enzyme A*. While here (referring to excerpts

in the test question) it is stated that: *Tricarboxylic acid cycle is formation of 6-carbon acid when pyruvic acid joins with 4-carbon acid*. So to me, the answer is false".

Results from the protocol data analysed further indicated that some learners use thematic pattern analysis to justify the answers to test questions, as illustrated in Blessing's verbalization on the relationship between nerve impulses and sensory neurons: "*The answer is true because nerve impulse and sensory impulses are in the same phases. They (sensory neurons) all carry information*". The metalinguistic skill demonstrated in Protocol data above is illustrative of what Lemke (1990) describes as talking science. As the Protocol data shows, Blessing also reckoned that the terms *nerve impulse* and *sensory impulses* are "in the same phases". This deduction is an implicit reference to thematic pattern because both terms belong to the same grammatical constituent when mapped on a transitivity table.

8.2.6.3 Research question 6c

Results of the LCT informed analysis proved to be useful because it uncovers the organising codes or principles underpinning knowledge construction in Nigerian and South African high school textbooks on life sciences. The analysis specifically revealed that terms in science textbooks are structured according to different levels of abstraction or information load, which can be characterised as either meaning with high semantic density (SD+) or meaning with low semantic density (SD-). It also revealed that authors of textbooks blend these knowledge types in different proportions to describe causal and existential scientific realities. A qualitative analysis of the protocol data further showed a correlation between instances when participants got correct answers to test questions and instances where the semantic density of a term is lowered from (SD+) to (SD-) as is the case in Protocol data 16: "*Umh from the question here, osmosis is the passage of*

molecules of solvent from a dilute solution to a more concentrated solution and here, osmosis is defined

as the movement of water particles from a dilute solution to a more concentrated solution. Solvent here

represent water or the liquid part of the solution, so the answer must be true".

As indicated in this Protocol data 16, the learner was able to unpack the science content on osmosis in the reference text: "*Solvent* here represent water or the liquid part of the solution". The weakening of semantic density (SD-) by the use of water as a variant of solvent facilitated the choice of the correct answer to the test question by the other participants. This fact is consistent with the findings that shifts in the strengths of semantic density and gravity in teacher talk are "crucial to cumulative knowledge building and key to academic literacy" (Maton, 2014: 1). It is also consistent with a theoretical prediction in LCT that "high-stakes reading is mediated as series of semantic waves in the knowledge expressed in classroom interaction" (Maton, 2014:10). It however contradicts our initial observation that learners were challenged by the different typologies of term variants identified by Gerzymisch-Arbogast (1996 & 2008) where a term for a concept in the reference text is substituted with a variant in the test question.

8.2.7   Research question 7: What methods of teaching can be developed to address the issue of term variation observed in life sciences textbooks?

To address the research question on the type of teaching methods that can be used to address the negative effects of term variation on learners' performance in the life sciences, we proposed a framework for content integrated terminology literacy and illustrated how it can be integrated into teaching and learning science. The proposed framework, which is underpinned by insights from systemic functional linguistics and legitimation code theory has three major components. They include: a first stage on sensitisation to terms, a second stage on sensitisation to variant terminology

and a third stage which has to do with confirmatory procedures or heuristics for identifying and verifying conceptual equivalence between terms. Although the proposed framework needs to be further tested, the framework can serve as a possible framework for responding to terminology variation in science textbooks. It is also believed to provide a promising solution to the crisis in science literacy in high schools.

8.3 Major conclusions from the synthesis of the qualitative and quantitative findings

The outcome of the synthesis of quantitative and qualitative findings outlined in the preceding section of the study led to the following major conclusions.

The context specific term model proposed by Gerzymisch-Abogast (2008) provided us with a broader framework for describing the types of term variant observed in Nigerian and South African textbooks. Thus a slightly modified typology of term variants was developed that comprises Type 1 variation or contamination of similarity, Type 2 variation or contamination of inclusion and Type 3 variation or contamination of intersection. The manifestations of term variants in Nigerian and South African life sciences textbooks for high school is pervasive, with a distribution that is even across Nigerian and South African life sciences textbooks but skewed across the constituents of the clauses of the Nigerian and the South African life sciences textbooks analysed.

Contrary to what is often reported about the positive effects of language proficiency in science achievement, it was not found to be a correlate of achievement in the test on processing variant terminology within and between tested Nigerian and South African learners. In view of the above, the recommendations proffered in Evans (1976) that synonymy (resulting from the use of term

variants) should be eliminated or that the terminology load of science textbooks should be reduced (because they can block learning and lead to poor comprehension) need to be revisited.

Term variation has a high functional value in high school life sciences textbooks, as indicated by the positive effects established between the science competence of learners and achievement in tasks on processing variant terminology. Findings from both the qualitative and quantitative results suggest that the use of term variants in science textbooks can serve as points of entry to the understanding of knowledge encoded in specialised texts.

The application of the proposed terminology literacy in content areas across the curriculum and the awareness that knowledge units (terms) in specialised texts (e.g. life sciences textbooks) are structured as waves of meanings with different semantic densities are promising skills that learners can use to respond to challenges posed by term variation in textbooks. These metalinguistic skills are beneficial to science learning and thus have strong potential for addressing the crisis of science literacy in high school education.

8.4   Recommendations and directions for future research

In recent years, both language and science educationists have made considerable progress toward resolving the crisis of science literacy in high school education. In language education, there is general consensus that language proficiency is a predicator of achievement in science. In science education, a benchmark used is the OECD PISA framework (2015) which conceptualised scientific literacy as a range of competencies used for explaining scientific phenomena, evaluating and designing scientific inquiry and interpreting data and evidence scientifically. Other particular skills include the ability to use mental models in different settings (Lijnse, 1990) and the ability to identify different kinds of knowledge encoded in text (see Resnick & Ford 2012).

In view of the above, the conceptual nature of language proficiency and scientific literacy needs to be redefined. From the perspective of this study, the revised framework should be indexed by any or a combination of the following: transitivity analysis, thematic pattern analysis and legitimation code theory analysis of the meanings encoded by terms. These skills are all consistent with what Cummins describes as Cognitive Academic Language Proficiency (CALP). They are also compatible with recommendations that scientific literacy should include the ability to detach content from contexts (Kauertz et al., 2012) and the ability to identify different kinds of knowledge that are linked by functional relations (see Resnick & Ford 2012).

The content integrated terminology framework we proposed and illustrated could be beneficial to tuition. The emphasis it gives to the development of skills for identifying the meaning potentials in texts could be exploited by teachers and integrated into teaching subjects across the curriculum. Learners in turn could integrate their acquisition of the metalinguistic skills illustrated in the lesson plan to their own independent learning process. Besides possibly laying a foundation for pedagogies that would address the high rate of underachievement in science and mathematics, the proposed content integrated terminology framework could also address the knowledge gap in science and sociology of education where it has been argued that subject matter or content knowledge and how it is structured has been under-theorised (Wheelahan, 2010; Young, 2013; Maton, 2014). In order to foster generalisability, however, the framework needs to be further tested to determine its efficacy. The application of the proposed framework might provide useful insights for its future development.

A large body of research exists in support of the claim that the structuring of knowledge in pedagogic discourse (e.g. textbooks and teacher talk) as waves of semantic density and gravity provides epistemological access to the knowledge encoded in specialised knowledge texts (see Maton, 2013; Maton & Martin, 2014; Matruglio et al., 2013). Toolkits from the different dimensions of LCT can provide keys that learners can use to crack the knowledge code in science textbooks or uncover how scientific reality is construed in science textbooks.

The results of the qualitative analysis of Nigerian and South African textbooks indicated that knowledge in science textbooks is not structured as a static meaning code but rather as waves of high and low semantic density and gravity (Maton, 2013). The organising principle underlying this practice needs to be reflected in the manner in which science textbooks are written by authors and also in the way teachers are taught to use these textbooks in their classrooms. A joint workshop for teachers and publishers of school textbooks with a view to sensitising them to the dynamics of terminology in science textbooks could be useful in this regard.

Previous algorithms for determining text readability measures, e.g. the Kincaid-Flesch, Gunning Fog and Lindau-Liu readability indexes have been criticised for their extreme reliance on the use of individual words to determine the level of text difficulty. The analysis of textbooks based on the interaction of words using constructs from legitimation code theory semantics could serve as a useful appraisal technique for determining text difficulty. Examining bodies in both Nigeria and South Africa, syllabus designers and planners and teachers could use this approach to select textbooks for teaching and assessment purposes.

The test on identification and responding to term variation (TIRTV) has proven to be a reliable instrument that can be used or adapted to test both cognitive academic language proficiency and scientific literacy. The research test questions, which had a Cronbach alpha reliability measure of (10-item test α = 0.70), could also be used to determine the language variable of contextual effect in the absence of a standard instrument for such in school effect research.

Future research on the dynamics of knowledge in science textbooks should test the theoretical assumption, hinted at in Antia and Kamai (2006), that specialised texts offer simultaneously several sources of information or control (e.g. terms, graphics, thematic patterns and inter-textuality) as a way of remedying any inadequacies associated with any of the given sources. This insight can be used to model the fluctuation and control dynamics of knowledge in scientific texts.

Lastly, findings from the study indicated that participants got correct answers to test questions wherever the semantic density of a term is stepped down from a meaning with high semantic density (SD+) to a meaning with low semantic density (SD-) and vice versa. An additional research endeavour worth pursuing is the need to subject to empirical analysis claims made on the functional value of term variation. For instance, a large study sample is needed to confirm the theoretical prediction in LCT semantics that substituting an abstract term with a contextualised or familiar one can facilitate a faster and easier way to understand how content knowledge is mediated in life sciences textbooks (Maton, 2013; Matruglio et al., 2014).

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APPENDIX 1: TERM VARIATION IN NIGERIAN AND SOUTH AFRICAN LIFE SCIENCES TEXTBOOKS FOR HIGH SCHOOL

Term variation in Nigerian Biology textbooks

Typology and manifestations of term variants in the clause constituents describing mode of nutrition in plants

sources between 'insects and other small invertebrates' 'insects and other small animals' and 'insects and other small organisms'.

Function	Actor	Process: Material Verb	Goal		Typology of variation
Class	Nominal group		Nominal group		**Actor:** Ideal relation in New Biology and Essential Biology
NEW BIOLOGY	carnivorous or insectivorous plants	trap	insects and other small invertebrates		involving the consistent use of the disjunctive 'carnivorous or insectivorous plants', contamination of similarity between 'carnivorous plants' and 'carnivorous or insectivorous plants' in College Biology and New Biology/Essential Biology.
COLLEGE BIOLOGY	carnivorous plants	trap	insects	and other small animals	
ESSENTIAL BIOLOGY	carnivorous or insectivorous plants	trap	insects	and other small organisms	**Process**: Ideal relation involving the consistent use of 'trap' across the three text sources.
					Goal: contamination of similarity across the three text

Typology and manifestations of term variants in the clause constituents expressing the functions of sensory neurones

Function	Actor	Process: Material	Goal	Circumstances: Place		Typology of variation
Class	Nominal group	Verb	Nominal	Place α (αlpha)	Place β (beta)	**Actor:** Ideal relation involving the consistent use of 'sensory neurone' in New Biology and College Biology; contamination of similarity intra-textually between 'sensory neurone' and 'afferent neurone' in New Biology. There is also contamination of similarity intra-textually
NEW BIOLOGY	sensory (afferent) neurones	transmit	impulses	from receptors	to the CNS	
COLLEGE BIOLOGY	sensory neurones	carry	impulses	from stimulus receptors	to the CNS	between 'sensory neuron' and 'afferent neuron' in Essential Biology; contamination of
ESSENTIAL BIOLOGY	Sensory(afferent) neurons	transmit	impulses	from sensory cells	towards the CNS (brain & spinal cord)	similarity across the three text sources between 'sensory(afferent) neurone' in New Biology, 'sensory neurone' in College Biology and the orthographic variant 'sensory(afferent) neuron' in Essential Biology (NB: the spelling of "neurone" with and without a final 'e').

Process: Ideal relation in New Biology and Essential Biology involving the consistent use of 'transmit'; contamination of similarity between 'carry' in College Biology and 'transmit' in New Biology and Essential Biology.

Goal: Ideal relation involving the consistent use of 'impulses' across the three text sources.

Place alpha: Contamination of similarity across the three text sources involving the use |

					of the variants 'receptors', 'stimulus receptors' and 'sensory cells'. **Place beta:** Ideal relation in New Biology and College Biology involving 'CNS'; Contamination of inclusion intra-textually in Essential Biology involving 'CNS' and 'Brain & Spinal cord', which are two compartments of the central nervous system (Schnell et al, 1999).

Typology and manifestations of term variants in clause constituents describing the functions of motor neurones

Function Class	Actor Nominal group	Process: Material Verb	Goal Nominal	Circumstances: Place		Typology of variation
				Place α(alpha)	Place β (beta)	
NEW BIOLOGY	motor neurone	transmits	impulses	from the CNS	to the effector	**Actor:** Ideal relation occurs across all texts involving 'motor neurones'. Ideal relation is also exemplified in College Biology and Essential Biology involving the use of the doublet 'motor(efferent) neurone'; contamination of similarity between 'motor neurone' which occurs across all texts and 'efferent neurones' in College Biology and Essential Biology.
COLLEGE BIOLOGY	motor (efferent) neurone	transmits	impulses	from the CNS	to the effector (muscle & gland)	**Process:** Ideal relation across the three text sources involving the consistent use of 'transmits'.
ESSENTIAL BIOLOGY	motor (efferent) neurone	transmits	impulses	from the CNS	to the effector organ	**Goal:** Ideal relation across the three text sources involving the consistent use of 'impulses'. **Place alpha:** Ideal relation across the three text sources involving the use of 'CNS'. **Place beta:** Contamination of inclusion between 'effector' in New Biology and 'effector organ' in Essential Biology. This is because an effector is "any peripheral tissue that receives nerve impulses and reacts by muscular contraction while an effector organ is a muscle or gland that contracts or secretes, in direct response to nerve impulses" (*Farlex Partner Medical Dictionary*, 2012:50); contamination of inclusion intra-textually in College Biology involving 'effector' and 'muscle & gland'.

Typology and manifestations of term variants in clause constituents describing the process of osmosis

Function	Token	Process: Relational	Value				Typology of variation
			Prep	Goal	Place α (αlpha)	Place β (beta)	
Class	**Nominal group**	**Verbal group**	**Prep**	**Adjectival group**			
NEW BIOLOGY	osmosis	is the passage	of	molecules of solvent	from a low concentrated solution	to a more concentrated solution	**Token:** Ideal relation across the three text sources involving the consistent use of 'osmosis'.
COLLEGE BIOLOGY	osmosis	is the diffusion	of	water molecules	from a region of low osmotic pressure	to a region of high osmotic pressure	**Process:** contamination of similarity involving the use of the variants in the verbal group 'passage' in New Biology; 'diffusion' in College Biology and 'flow' in Essential Biology.
ESSENTIAL BIOLOGY	osmosis	is the flow	of	water molecules	from a region of diluted or weaker solution	to a region of high concentration	**Goal:** Ideal relation in College Biology and New Biology involving the use of 'water molecules'; contamination of similarity involving 'molecules of solvent' in New Biology and 'water molecules' in Essential Biology and College Biology.

Place alpha: contamination of similarity involving the use of 'low concentrated solution' in New Biology, 'region of low osmotic pressure' in College Biology. Contamination of similarity is also exemplified intra-textually in Essential Biology involving the use of 'region of diluted solution' and 'region of weaker solution'.

Place beta: contamination of similarity across the three text sources involving the use of 'more concentrated solution' in New Biology, 'region of high osmotic pressure' in College Biology and 'region of high concentration' in Essential Biology. |

Typology and manifestations of term variants in clause constituents describing the **nervous** system

Function	Token	Process: Relational	Value	Typology of variation
Class	**Nominal group**	**Verbal group**	**Nominal group**	**Token:** Ideal relation in New Biology and College Biology involving the consistent use of 'nervous system' ; contamination of inclusion between 'brain and spinal cord' in Essential Biology and 'nervous system' in New Biology and College Biology. (Rationale: The former comprises the central nervous system (Schnell et al, 1999).
NEW BIOLOGY	the nervous system	consists	of nerve cells or neurones	
COLLEGE BIOLOGY	the nervous system	consists	of neurones (nerve cells)	
ESSENTIAL BIOLOGY	the brain and spinal cord	consists	of neurones (nerve cells)	**Process:** Ideal relation across the three text sources involving the consistent use of 'consists'. **Value:** Ideal relation in College Biology and Essential Biology involving the consistent use of the doublet 'neurones (nerve cells); contamination of similarity intra-textually involving the disjunctive variant 'nerve cells or neurones' in New Biology and the doublet 'neurones (nerve cells)' in College Biology and Essential Biology.

Typology and manifestations of term variants in the clause constituents describing photosynthesis

Function	Actor	Process: Material	Goal	Circumstances	Typology of variation
Class	Nominal group	Verb	Adjectival group		**Actor:** Ideal relation across the three text sources involving the use of 'green plants'.
NEW BIOLOGY	green plants	use	radiant energy or light	as source of energy	**Process:** Ideal relation across the three text sources involving the use of the non-technical term 'use'.
COLLEGE BIOLOGY	green plants	use	sunlight energy	to manufacture food	**Goal:** contamination of similarity intra-textually in New Biology between 'radiant energy' and 'light'; contamination of similarity across the three text sources involving the disjunctive 'radiant energy or light' in New Biology and term variants (sunlight energy) in college biology and 'sunlight' in Essential Biology.
ESSENTIAL BIOLOGY	green plants	use	sunlight	to manufacture food	**Circumstances:** Ideal relation in College Biology and Essential Biology involving the consistent use of 'manufacture food'; Contamination of similarity between 'source of energy) in New Biology and 'manufacture food' in College Biology and Essential Biology.

Typology and manifestations of term variants in the clause constituents describing nervous coordination

Function Class	Actor Nominal group	Process: Material Verb	Circumstances: Place		Typology of variation
			Place α(alpha)	Place β (beta)	**Actor:** Ideal relation in College Biology and Essential Biology involving the consistent use of 'association or intermediate neurone'; contamination of similarity between 'relay neurone' in New Biology and 'association or intermediate neurone' in College Biology and Essential Biology.
NEW BIOLOGY	relay neurone	links	sensory neurone	with motor neurone	
COLLEGE BIOLOGY	association or intermediate neurone	connects	sensory neurone	and motor neurone	
ESSENTIAL BIOLOGY	association or intermediate neurone	joins	sensory neurone	with motor neurone	

Process: Contamination of similarity across the three text sources involving the use of the variants 'links' in New Biology; 'connects' in College Biology and 'joins' in Essential Biology.

Place alpha: Ideal relation across the three text sources involving the consistent use of 'sensory neurone'.

Place beta: Ideal relation across the three text sources involving the consistent use of 'motor neurone'.

Typology and manifestations of term variants in clause constituents describing the process of nitrification in the nitrogen cycle

Function Class	Token Nominal	Process: Relational Verbal group	Value			Typology of variation
			Prep	Nominal Group (αlpha)	Nominal Group (beta)	**Token:** Ideal relation across the three text sources involving the consistent use of 'nitrification'.
NEW BIOLOGY	nitrification	is conversion	of	organic nitrogenous compounds	into inorganic nitrogenous compounds	**Process:** Ideal relation across the three text sources involving the consistent use of 'is conversion'.
COLLEGE BIOLOGY	nitrification	is conversion	of	ammonia	into nitrite or nitrate	**Nominal Group alpha:** Contamination of intersection involving 'organic nitrogenous compounds' in New Biology and 'ammonia' in College Biology Rationale:
ESSENTIAL BIOLOGY	nitrification	is conversion	of	ammonium compounds	into nitrite and nitrate	[xxxx] Contamination of intersection between 'organic nitrogenous compounds' in New Biology and 'ammonium compounds' in Essential Biology. There are other examples of organic nitrogenous compounds, e.g. the amines, azides and the oxides (Pohanish & Greene, 2009:).
						Nominal Group beta: Contamination of similarity in College Biology and Essential Biology involving the use of the disjunct 'nitrite and nitrate' and the conjunctive variant 'nitrite and nitrate' in Essential Biology. Contamination of intersection involving 'inorganic nitrogenous compounds' in New Biology and 'nitrite or nitrate' in College Biology and 'nitrate and nitrate' in Essential Biology. Nitrite and nitrate are not the only examples of inorganic nitrogenous compounds, others are: nitric oxide, nitrogen dioxide, nitrogen trichloride, etc. (Ignaro, 2000:57).

Typology and manifestations of term variants in clause constituents defining the Krebs' cycle

Function	Token	Process: Relational	Value				Typology of variation
Class	Nominal Group	Verbal group	Goal	Adverbial Group	Verbal Group	Nominal Group	
NEW BIOLOGY	Krebs' cycle	is formation	of citric acid	when pyruvic acid	converts	acetyl co-enzyme a	**Token:** Ideal relation involving the use of 'Krebs' cycle' across all three texts, with Essential Biology also having the disjunctively connected 'tricarbozylic acid cycle' which exemplifies contamination of similarity with 'Krebs' cycle'.
COLLEGE BIOLOGY	Krebs' cycle	is formation	citric acid or 6-carbon acid	when pyruvic acid or 6-carbon acid	joins with	4-carbon acid or oxaloacetic acid	**Process:** Ideal relation across the three text sources involving the use of 'is formation'. **Goal:** Ideal relation involving the consistent
ESSENTIAL BIOLOGY	Krebs' cycle or tricarboxylic acid cycle	is formation	of citric acid	when pyruvic acid	combines with	acetyl co-enzyme a	use of 'citric acid' across all three texts, with College Biology having the disjunctive 'citric acid or $_6$-carbon acid' both of which exemplify contamination of similarity. Ccitric acid refers to the chemical name and $_6$-carbon acid refers to the molecular formula. **Adjectival Group:** Ideal relation across the three textbooks involving the consistent use of 'pyruvic acid', with College Biology having contamination of similarity intra-textually in the disjunctive variant describing the chemical name of the acid 'pyruvic acid'

							and '$_6$-carbon acid' which describes the molecular formula of the acid.
							Verbal Group: contamination of similarity across the three text sources involving the use of the variants 'converts', 'joins' and 'combines'.
							Nominal Group: Ideal relation involving the consistent use of 'acetyl co-enzyme A' in New Biology and Essential Biology; contamination of similarity intra-textually in College Biology involving the disjunctive variant '4-carbon acid or oxaloacetic acid', which describes both the molecular formula and the chemical name of the acid respectively.

Typology and manifestations of term variants in clause constituents describing anaerobic respiration

Function	Existent	Process: Existential	Phenomena			Typology of variation
Class	Nominal	Verbal group	Alpha(α)	Beta(β)	Gamma (γ)	**Existent:** Ideal relation across all three texts involving the consistent use of 'glucose'; contamination of inclusion intra-textually in Essential Biology involving the use of the disjunctive variants 'sugar or glucose'.
NEW BIOLOGY	glucose	is broken down	to ethyl alcohol	carbon dioxide	and energy	
COLLEGE BIOLOGY	glucose	is broken down	to alcohol	carbon(iv)oxide	and energy (ATP)	**Process:** Ideal relation across the three text sources involving the consistent use of 'broken down'.
ESSENTIAL BIOLOGY	sugar or glucose	are broken down	to alcohol (ethanol)	carbon dioxide	and energy	**Phenomena** **Alpha:** Contamination of similarity between 'ethyl alcohol' in New Biology and 'alcohol' in College Biology**.** This is because both terms have similar chemical formula C_2H_5OH. Contamination of similarity intra-textually in Essential Biology involving the doublet 'alcohol (ethanol)'. **Beta:** Ideal relation in New Biology and Essential Biology involving 'carbon dioxide'; contamination of similarity between the chemical formula 'carbon (IV) oxide)' in College Biology and the chemical name 'carbon dioxide)' in New Biology and Essential Biology. **Gamma:** Ideal relation between New Biology and Essential Biology involving the use of (energy); contamination of similarity intra-textually in College Biology involving the use of the doublet (energy (ATP).

Term variation in South African life sciences textbooks

Note that although the focus is on variation in terms, not every varying item in the clause constituents as presented in the tables will necessarily be a term. For reason of space, the following abbreviations will be used: **SMLS:** Study and Master Life sciences **OSLS:** Oxford Successful Life sciences **FLS:** Focus Life Sciences.

Typology and manifestations of term variants in the clauses describing the functions of sensory neurons

Function	Actor	Process: Material	Goal	Circumstances: Place		Typology of variation
Class	Nominal group	Verbal group	Nominal group	Place α (alpha)	Place β (beta)	**Actor:** ideal relations involving 'sensory neurons' in SMLS and OSLS; contamination of similarity intra-textually in FLS involving the disjunctive variant 'nerve cells or neurons'; contamination of intersection between the superordinate term 'neurons' in FLS and 'sensory neurons' which is only a category subsumed under neurons (others being motor and relay neurons).
SMLS	sensory neurons	carry	impulses	from the receptors	to the brain and spinal cord	
OSLS	sensory neurons	transmit	information	from the receptors	to the(CNS) central nervous system	
FLS	nerve cells or neurons	carry	messages (electrical impulses)	from one part of the body	to the brain and spinal cord	**Process:** Ideal relation involving 'carry' in SMLS and FLS; contamination of similarity between 'carry' in SMLS and FLS and 'transmit' in OSLS.
						Goal: Contamination of similarity across the three text sources involving 'impulses' in SMLS; 'information' in OSLS and the doublet 'messages (electrical impulses)' in FLS. Contamination of

					similarity intra-textually involving the doublet 'messages (electrical impulses)' in FLS.
					Place alpha: ideal relation involving 'receptors' in SMLS and OSLS; contamination of inclusion between 'parts of the body' in FLS and 'receptors' in SMLS and OSLS. (Rationale: All parts of the body respond to stimulus because it consists of receptors ().
					Place beta: Ideal relation involving 'brain and spinal cord' in SMLS and FLS; contamination of similarity intra-textually in OSLS between the abbreviation 'CNS' and the full form 'central nervous system'. There is also contamination of inclusion between 'brain & spinal cord' in New Biology and FLS and CNS 'central nervous system' in OSLS.

Typology and manifestations of term variants in clauses describing the functions of motor neurones

Function Class	Actor Nominal group	Process: Material Verb	Goal Nominal	Circumstances: Place		Typology of variation
				Place α (αlpha)	Place β (beta)	
SMLS	motor neurons	carry	impulses	from brain & spinal cord	to the effectors (muscles & glands)	**Actor:** Ideal relation involving 'motor neurons' across all three texts, with a slight orthographical variation in the spelling of neurons in OSLS (NB: Notice the spelling of neurone with and without a final 'e'); contamination of similarity intra-textually in OSLS involving the doublet 'motor (efferent) neurones'.
OSLS	motor(efferent) neurones	transmit	impulses	from the cns	to the effectors (muscles & glands)	
FLS	motor neurons	conduct	impulses	from cns	to the effectors (muscles & glands)	**Process:** contamination of similarity across the three text sources involving the synonymic chain 'carry' in SMLS, 'transmit' in OSLS and 'conduct' in FLS.

Goal: Ideal relation across the three text sources involving the congruent use of 'impulses'.

Place alpha: Ideal relation in OSLS and FLS involving the consistent use of 'CNS'; contamination of inclusion in SMLS involving the conjunctive variant 'Brain & Spinal Cord' and 'CNS' in OSLS and FLS.

Place beta: ideal relation across the three texts involving the consistent use of the doublet 'effectors 'muscles and glands'.

Typology and manifestations of term variants in clauses describing the process of osmosis

Function	Token	Process: Relational	Goal	Value: Place		Typology of variation
Class	Nominal	Verbal group	Adjectival group	Place α (αlpha)	Place β (beta)	**Token:** Ideal relation in all the three text sources involving 'osmosis'. Ideal relation is also exemplified in SMLS and FLS involving the consistent use of 'diffusion'.
SMLS	osmosis	is diffusion	of water molecules	from a region of high concentration	to a region of low concentration	**Process:** Contamination of similarity between 'diffusion' in SMLS and 'movement' in OSLS; contamination of similarity intra-textually in FLS involving the doublet 'movement (diffusion)'.
OSLS	osmosis	is movement	of water molecules	from an area of high water potential	to an area of low water potential	**Goal:** Ideal relation involving 'water molecules' in SMLS and OSLS; contamination of similarity between 'particles' in FLS and 'water molecules' in OSLS and SMLS.
FLS	osmosis	is movement (diffusion)	of particles	from high concentration of water molecules	to low concentration of water molecules	**Place alpha:** Contamination of similarity across the three text sources involving the use of 'region of high concentration' in SMLS; 'area of high water potential' in OSLS and 'high concentration of water molecules' in FLS. **Place beta:** Contamination of similarity across the three text sources involving the use of 'region of low concentration' in SMLS; 'area of low water potential' in OSLS and 'low concentration of water molecules' in FLS.

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Typology and manifestations of term variants in clauses describing the process of diffusion

Function Class	Token Nominal	Process: Relational Verbal group	Goal Nominal group	Value: Place		Typology of variation
				Place α (αlpha)	Place β (beta)	
SMLS	diffusion	is movement	of molecules of a substance (solid, liquid and gas)	from a region of high concentration	to a region of low concentration	**Token:** Ideal relation across the three text sources involving the consistent use of 'diffusion'. **Process:** Ideal relation involving the use of 'movement' consistently across the three text sources.
OSLS	diffusion	is movement	of water particles	from an area of high concentration	to an area of low concentration	**Goal:** There is ideal relation involving the consistent use of 'molecules' in SMLS and FLS. Contamination of inclusion intra-textually involving 'molecules of a substance' and 'solid, liquid and gas' in SMLS; contamination of similarity between 'water particles' in OSLS and 'molecules' in FLS.
FLS	diffusion	is movement	of molecules	from a region of high concentration	to a region of low concentration	**Place alpha:** Ideal relation manifests in the Place Alpha slot in SMLS and FLS involving the use of **'**region of high concentration' in SMLS and FLS Contamination. of similarity manifests acrss the three text sources involving the use of 'region of high concentration' in SMLS and OSLS and 'area of high concentration' in FLS.
						Place beta: Ideal relation also manifests in the Place beta slot involving the consistent use of 'region of low concentration' in SML and contamination of similarity across the three text sources involving the use of 'region of low concentration' in SMLS; 'area of low concentration' in OSLS and 'region of low concentration' in FLS.

Typology and manifestations of term variants in the clause constituents of text excerpts on the function of nitrogen fixing bacteria in the nitrogen cycle

Function Class	Actor Nominal group	Process: Material Verb	Goal Adjectival group	Circumstances Prepositional group	Typology of variation
SMLS	nitrogen fixing bacteria	converts	nitrogen gas	to nitrates (NH3)	**Actor:** Ideal relation involving 'nitrogen fixing bacteria' in SMLS and FLS; contamination of intersection between the superordinate term 'nitrogen fixing bacteria' in SMLS and FLS and the subordinate 'nitrobater' in OSLS. (Rationale: This is because there are many other types of nitrogen fixing bacteria, e.g. nitrosomonas**).**
OSLS	nitrobacter	converts	atmospheric nitrogen	to nitrates	
FLS	nitrogen fixing bacteria	changes	nitrogen gas	to nitrates (NH3)	**Process:** Ideal relation involving 'converts' in SMLS and OSLS; contamination of similarity between 'converts' in SMLS and OSLS and 'changes' in FLS. **Goal:** Ideal relation between (nitrogen gas) in SMLS and FLS; contamination of similarity between 'nitrogen gas' in SMLS and FLS and 'atmospheric nitrogen' in OSLS. **Circumstances:** Ideal relation intra-textually involving the use of the doublet that combines the chemical name 'nitrates' and molecular formula 'NH3' in SMLS and FLS; contamination of similarity between the variant with the chemical name and molecular formula 'nitrates (NH3)' in SMLS and FLS and 'nitrates' in OSLS, which refers to only the molecular formula.

Typology and manifestations of term variants in clauses describing the process of denitrification in the nitrogen cycle

Function Class	Actor Nominal group	Process: Material Verb	Goal Nominal	Circumstances Prepositional group	Typology of variation
SMLS	denitrifying bacteria	converts	nitrates	to N$_2$ in the air	**Actor:** ideal relation involving 'denitrifying bacteria' in SMLS and FLS, contamination of intersection between 'pseudomonas thiobacilus' in OSLS and 'denitrifying bacteria' in SMLS and FLS. (Rationale: This is because there are many other types of denitrifying fixing bacteria, e.g. Paracoccus denitrificans (Stroh et al, 2004)**.**
OSLS	pseudomonas and thiobacillus	change	nitrates	to nitrogen gas	**Process:** contamination of similarity involving the variants 'converts' in SMLS; 'changes' in OSLS and 'breaks down' in FLS.
FLS	denitrifying bacteria	breaks down	nitrates	to nitrogen gas	**Goal:** Ideal relation involving 'nitrates' across the three text sources.

Circumstances: Ideal relation involving 'nitrogen gas' in OSLS and FLS; contamination of similarity between 'N$_2$ in the air' in SMLS and 'nitrogen gas' in OSLS and FLS. |

Typology and manifestations of term variants in clauses describing the structure of the human heart

Function	Existent	Process: Existential	Circumstances: Place		Typology of variation
Class	**Nominal group**	**Verbal group**	**Place α (αlpha)**	**Place β (beta)**	**Existent:** Contamination of similarity across the three text sources involving 'atrio-ventricular valves' in SMLS, 'bicuspid valves' in OSLS. There is also contamination of similarity intra-textually in FLS involving the doublet 'cupsid (atrio ventricular)' valves'. Contamination of similarity also manifests intra-textually in FLS involving 'cupsid valves' and 'atrioventricular valves'. **Process:** Ideal relation involving 'are found' in SMLS and OSLS and contamination of similarity between 'are found' and 'lie' in FLS. **Place alpha:** Ideal relation involving the 'atria' across the three text sources. **Place beta**: ideal relation involving the 'ventricle' across the three text sources.
SMLS	atrioventricular valves	are found	between the atria	and the ventricle	
OSLS	bicuspid valves	are found	between the atria	and the ventricle	
FLS	cuspid (atrioventricular) valves	lie	between the atria	and the ventricle	

Typology and manifestations of term variants clauses describing blood circulation

Function	Token	Process: Relational	Value		Typology of variation
			Circumstances		
			Place α (αlpha)	Place β (beta)	
Class	Nominal group	Verbal group			**Token:** Contamination of similarity across the three text sources involving 'systemic circuit' in SMLS; 'systemic circulation' in OSLS and 'systemic circulatory system' in FLS.
SMLS	systemic circuit	is blood circulation	to all parts of the body	and back to the heart	
OSLS	systemic circulation	is circulation of blood	to all parts of the body	ellipted	**Process:** Ideal relation involving 'is circulation of blood' in both OSLS and FLS; contamination of similarity between 'blood circulation' in SMLS and 'circulation of blood' in OSLS and FLS**.**
FLS	systemic circulatory system	is circulation of blood	to all parts of the body	and back to the heart	**Place alpha:** Ideal relation involving 'all parts of the body' across the three text sources. **Place beta:** Ideal relation in SMLS and FLS. The term for Place beta is however ellipted in OSLS.

Typology and manifestations of term variants in clauses describing the structure of a neurone

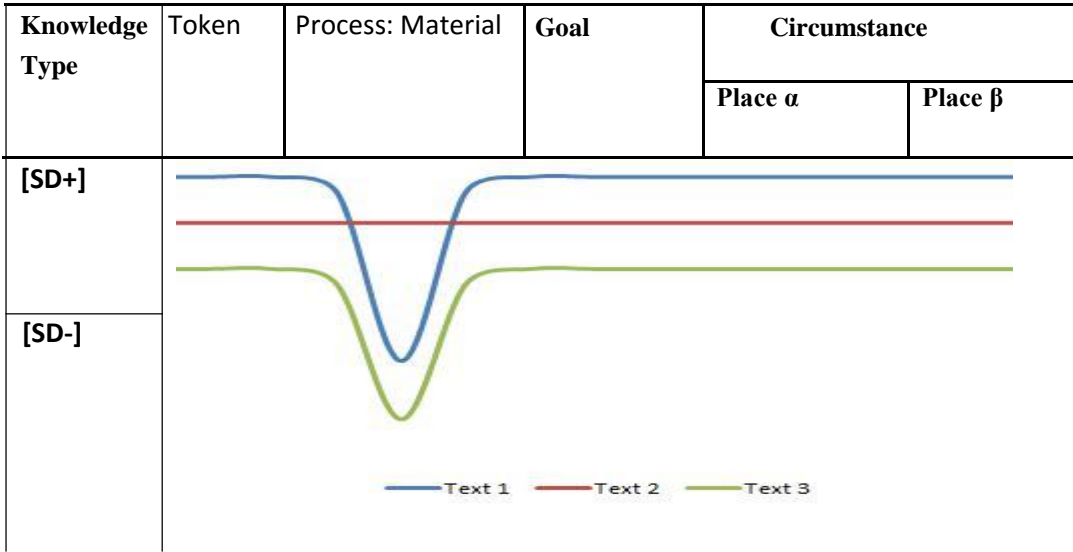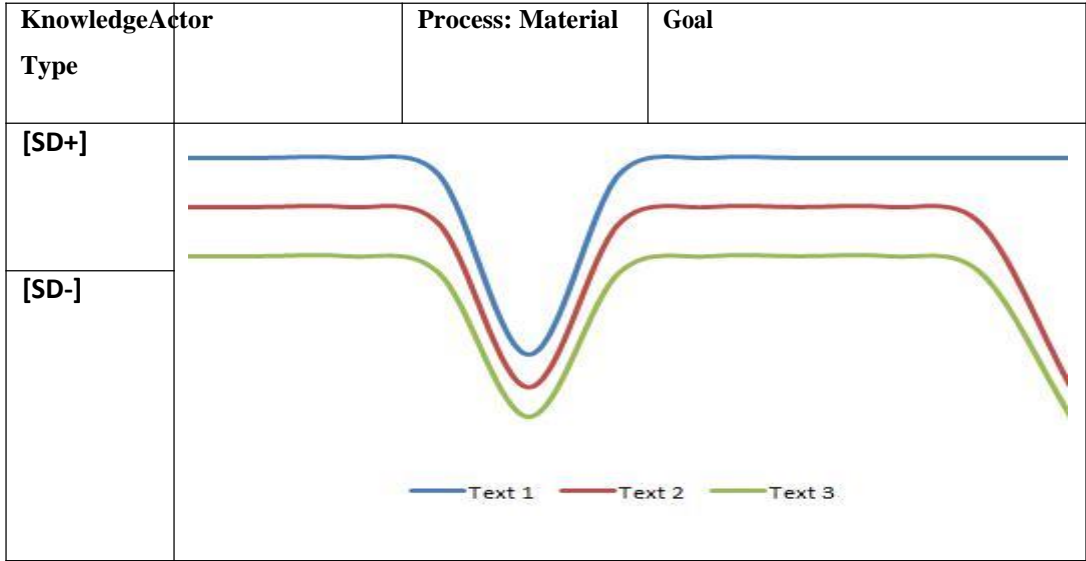| Function	Actor	Process: Material	Goal	Typology of variation
Class	Nominal group	Verb	Nominal	**Actor:** in each of the three texts there is contamination of similarity intra-textually: the doublet 'nerve fibres / projections' in SMLS; the disjunctive doublet 'outgrowth or thread' in OSLS and 'processes or long outgrowth' in FLS.
SMLS	nerve fibres/ projections	transmit	impulses	
OSLS	outgrowths or thread	conduct	impulses	**Process:** Ideal relation involving 'conduct' in OSLS and FLS; contamination of similarity between 'transmit' in SMLS and 'conduct' in OSLS and FLS.
FLS	processes or long outgrowths	conduct	impulses	**Goal:** Ideal relation involving 'impulses' across the three text sources.

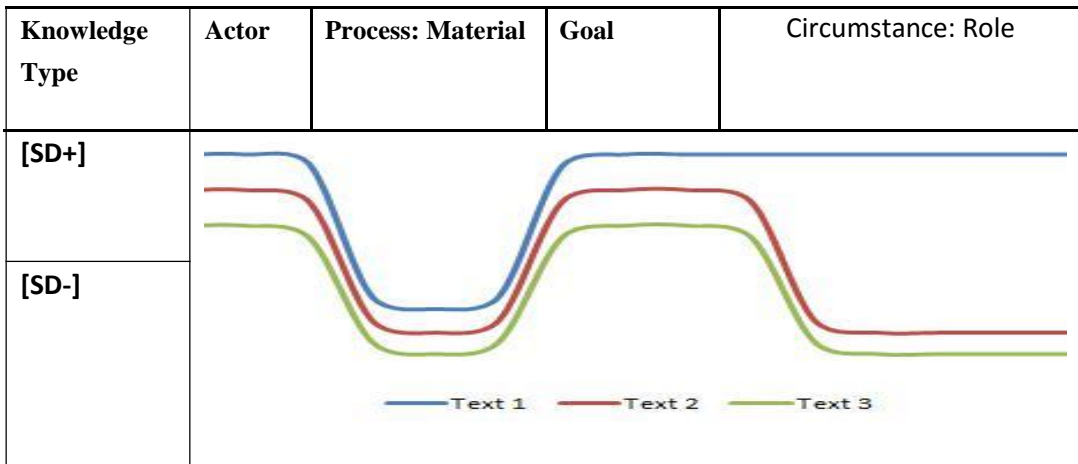**Typology and manifestations of term variants clauses constituents describing water transportation in plants**

Function	Token	Process:	Value			Typology of variation
Class	Noun	Relational verb	**Nominal group**	**Verbal group**	**Adverbial group**	**Token:** Ideal relation involving 'capillarity' in OSLS and FLS; contamination of similarity involving 'cohesion' in SMLS and 'capillarity' in OSLS and FLS.
SMLS	cohesion	is	a strong force of attraction	that allows	water to flow in continuous column	
OSLS	capillarity	is	a strong intermolecular force	which creates	continuous water column	**Process:** Non-term but ideal relation
FLS	capillarity	is	a force	that assists	continuous upward movement of water	**Nominal Group:** contamination of similarity involving 'strong force of attraction' in SMLS, 'strong intermolecular force' in OSLS and 'force' in FLS. **Verbal Group:** contamination of similarity across the three text sources involving 'allows' in SMLS; 'creates' in OSLS and 'assists' in FLS. **Adverbial Group:** contamination of similarity across the three text sources between 'water to flow in continuous column' in SMLS, 'continuous water column' in OSLS and 'continuous upward movement of water' in FLS.

APPENDIX 2: SEMANTIC WAVES IN NIGERIAN AND SOUTH AFRICAN LIFE SCIENCES TEXTBOOKS FOR HIGH SCHOOL

Semantic waves in Nigerian Biology textbooks

Knowledge Type	Actor	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Text 1   Text 2   Text 3

Knowledge Type	Actor	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Text 1   Text 2   Text 3

Knowledge Type	Actor	Process: Material	Goal	
[SD+] **[SD-]**				

Knowledge Type	Token	Process: Material	Goal	Circumstance	
				Place α	**Place β**
[SD+] **[SD-]**					

Knowledge Type	Token	Process: Relational	Nominal Group
[SD+]			
[SD-]			

Text 1　Text 2　Text 3

Knowledge Type	Actor	Process: Material	Goal	Circumstance: Role
[SD+]				
[SD-]				

Text 1　Text 2　Text 3

Knowledge Type	Actor	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Text 1   Text 2   Text 3

Knowledge Type	Token	Process: Material	Nominal Group	
			Alpha	Beta
[SD+]				
[SD-]				

Text 1   Text 2   Text 3
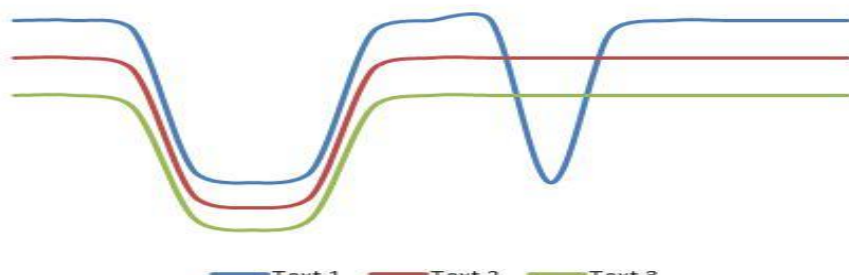
Knowledge Type	Token	Process: Relational	Goal	Group		
				Adjective	Verbal	Nominal
[SD+] [SD-]						

Knowledge Type	Token	Process: Existential	Phenomena		
			Alpha	Beta	Gamma
[SD+] [SD-]					

Semantic waves South African life sciences textbooks

Knowledge Type	Actor	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Knowledge Type	Actor	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Knowledge Type	Actor	Process: Material	Goal
[SD +]			
[SD-]			

Knowledge Type	Token	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Knowledge Type	Token	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Knowledge Type	Token	Process: Material	Goal	Circumstance: Place	
				Place α	Place β
[SD+]					
[SD-]					

Knowledge Type	Existent	Process: Existential	Circumstance: Role	
[SD+]				
[SD-]				
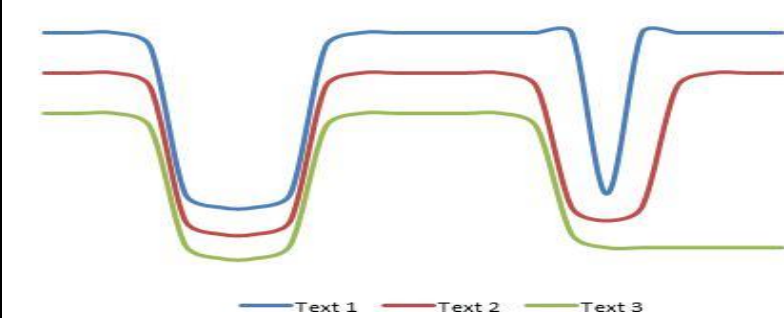
Text 1 — Text 2 — Text 3

Knowledge Type	Token	Process: Material	Goal	Circumstance	
				Place α	Place β
[SD+]					
[SD-]					

Text 1 — Text 2 — Text 3

Knowledge Type	Token	Process: Relational	Nominal Group Alpha	Nominal Group beta
[SD+]				
[SD-]				

Text 1 — Text 2 — Text 3

Knowledge Type	Token	Process: Relational	Value		
			Adjectival	verbal	Adverbial
[SD+]					
[SD-]					