POLYSEMY AND CONTEXT

TEACHERS' CLASSROOM LANGUAGE FOR UNDERSTANDING PHYSICAL SCIENCE

BY

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PROTOCOL NUMBER: 2015ECE004M

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN SCIENCE EDUCATION

IN THE

FACULTY OF SCIENCE
UNIVERSITY OF THE WITWATERSRAND

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NOVEMBER 5, 2016

ABSTRACT

A debate in South Africa on learner performance in Physical Science inevitably leads to the issue of proficiency in the language of learning and teaching (LoLT). The researcher is of the opinion that general understanding of the meaning of proficiency in LoLT usually refers to the ability to read and write well in that language which happens to be English in the majority of South African high schools. As low as 7% of the South African school going population regard themselves as English speaking (Department of Basic Education, 2010). The status of English as *lingua franca* has caused parents and teachers to believe that it is in the interest of learners to be taught in English (Wildsmith-Cromarty & Gordon, 2009). This view resulted that the debate on proficiency includes amongst others, opinions of those who propagate home language teaching and those who call for English as the preferred medium of instruction.

This research contributes to the debate on proficiency by pointing to the important contribution that the science teacher can make to enculturate learners into the language of school science. The fact that both English First Additional Language learners (EFALs) as well as English Home Language learners (EHLs) struggle to understand Physical Science (Probyn, 2015) is indicative of the important role that the science teacher can play in assisting learners to understand Physical Science. In lieu of this, teachers are encouraged to focus on vocabulary building as well as the manner in which LoLT is employed to construe science knowledge. This is a functional view of language, namely, that language is used to convey a particular meaning hence the language differs across registers. Michael Halliday (1993) is credited for the development of a systemic functional linguistic view on language.

This study analysed two teachers' classroom languages from a Systemic Functional Linguistic (SFL) perspective with specific emphasis on the register variables field and mode. Results show that LoLT was perceived as transparent when learners are EHLs and considered a barrier to learning Physical Science if learners are EFALs. In both cases, teachers seemed unable to enculturate learners into the language of school science when used to convey science meaning. An absence of that focus is what Bernstein called an "invisible pedagogy".

DECLARATION

I Regina White, declare that the research report, which I hereby submit for the degree Masters of Science in Science Education at the University of the Witwatersrand, is my own work and has not been previously submitted by me for a degree at this or any other tertiary institution.

SIGNATURE: ____________________

DATE: 5 November 2016

DEDICATION

This research is dedicated to my two girls who had to learn to become independent during mommy's pursuit of her dreams. May this experience spur them on to develop conducive environments for themselves in which they would be free to dream. To my son, thank you for the peace of mind you provided during this period by proving to be a dedicated and focused undergraduate student. To my husband, we did this during the most difficult time of our lives, fighting a battle against financial survival and being true to our respective callings. God is merciful! To my siblings who always inspire me to do better and my mother and father who prove that wise parenting can change generations.

ACKNOWLEDGEMENTS

I acknowledge God as the author and finisher of my faith. This desire to complete an MSc was planted in my being by Him and me writing this acknowledgement is only through His providence.

I wish to thank my supervisor Dr Emmanuel Mushayikwa for encouraging me to address the elephant in the room. This fostered critical engagement with literature. I appreciate that this in itself is a long journey.

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LIST OF ACRONYMS

LoLT	Language of Learning and Teaching
MST	Mathematics Science and Technology
HG	Higher Grade
DoE	Department of Education
NSMST	National Strategy for Mathematics, Science and Technology
LSS	Language of School Science
FAL	First Additional Language
FLLE	Foreign Language Learning Environment
EFALs	English First Additional Language Learners
EHLs	English Home Language Learners
TIMSS	Third International Mathematics and Science Study
ZPD	Zone of Proximal Development
SFL	Systemic Functional Linguistics
NSC	National Senior Certificate
FET	Further Education and Training

LIST OF APPENDICES

1 Chapter 1

Introduction and Orientation

1.1 Introduction

A debate in South Africa on learner performance in Physical Science inevitably leads to the issue of proficiency in the language of learning and teaching (LoLT). As low as 7% of the South African school going population regard themselves as English speaking (Department of Basic Education, 2010). The status that English has as *lingua franca* has caused parents and teachers to believe that it is in the interest of learners to be taught in English (Wildsmith-Cromarty and Gordon, 2009). This view resulted that the debate on proficiency include amongst others, opinions of those who propagate home language teaching and those who call for English as the preferred medium of instruction. Setati, Adler, Reed, and Bapoo (2002) advocate the concept of code-switching in South African schools to address the issue of proficiency amongst English First Additional Language learners (EFALs). Code-switching is the practice where teachers use two or more languages to communicate a point to their learners. These learners normally speak a language other than English at home and are therefore categorised as EFALs.

Valid reasons for a particular view is put forward on both sides of the debate. Proponents of English as preferred medium of instruction make a case for the absence of study material in learners' home language as they continue with tertiary education. They also argue that a solid grounding in English will ensure that learners do not struggle when they eventually have to learn in English. Desai (2016) indicated that some proponents fear that promoting home language as medium of instruction might lead to segregation or educational closure for learners. On the other end of the debate, it is argued that the link between language and cognitive development necessitates a firm grounding in home language before introduction of English.

The researcher is of the opinion that both views focus on proficiency in LoLT. The debate on proficiency, albeit an important first step for any learning to take place, obscures the very important aspect of learning science, namely, that learning Physical Science is akin to learning a language. Oyoo (2012) posits that, unless teachers teach learners the meaning of words used when teaching Physical Science, learners will be unable to perform on grade level in Physical Science tests and examinations. The proponents of code-switching also identify the need for the teacher to explain key concepts in the learners' language to promote conceptual understanding. This approach is a direct derivative from Lemke (1990) who claims that, in order for learners to do science, they must learn to speak the language of science.

The, at times, opposing views in the ongoing language debate calls for an analysis of the language that the science teacher uses to communicate science concepts. It is becoming clear that their language use can aid understanding provided it is carefully negotiated. For this study, teacher classroom language will be referred to as the language of school science (LSS). LSS is one of the terms (others include academic language (Nagy & Townsend, 2012), language of schooling and scientific English (Halliday & Martin, 1993)) given to the range of languages used in academic settings. Halliday (1993) developed a theory called systemic functional linguistics (SFL) as a means to analyse the functions of language as it is used to communicate academic knowledge. According to this theory, grammar is used to construe specific meaning. If learners are aware of the change in meaning that results because of specific grammatical choices, they would be more likely to understand the meaning potential of the utterance or text. This focus away from proficiency, as a measure of the ability to read and write in the LoLT, to an investigation of teachers' awareness of the importance of making LSS comprehensible to learners, will be investigated further in this report.

The rest of this chapter reports on the following: section 1.2 outlines the state of Mathematics, Science and Technology (MST) as benchmarked by the national examination results from 2002 to 2014. Thereafter, arguments are put forward for a perspective on learning and teaching Physical Science that should include a focus on LSS (section 1.3) followed by a look at a rationale for the study (section 1.4) and the problem statement (section 1.5). Section 1.6 states the aims of this study. The research questions that guided this study are stated in section 1.7 and section 1.8 provides a brief outline of the structure of this report.

1.2 National examinations benchmark the state of MST in South Africa

Table 1.1 below represents the pass rate of learners who entered the Physical Science Higher Grade (HG) examination for the period 2002-2007. The HG cohort is of interest here since this was the group of learners who were most likely to continue tertiary studies in MST related fields.

This period is a specific focus as it earmarks one year after the implementation of the National Strategy for Mathematics Science and Technology (NSMST) Education devised by the Department of Education (DoE) in 2001. The three key thrusts of this strategy were to

- increase participation and performance of previously disadvantaged individuals in Mathematics, Science and Technology;
- provide high quality education in Mathematics, Science and Technology and;
- increase and improve human resource capacity to deliver quality Mathematics, Science and Technology Education.

The strategy could not increase the uptake of Physical Science as is indicated in Table 1.1. Out of an average of 500 000 grade 12 learners who annually sat for the final examination from 2002 to 2007, only a twentieth passed Physical Science on the higher grade.

Table 1.1 Number of learners who passed HG Physical Science 2002-2007(Kriek & Grayson, 2009)

2002	2003	2004	2005	2006	2007
24,888	26,067	26,975	29,965	29,781	28,122
76,4%	80.3%	74.8%	73.2%	72.2%	70.2%

Considering the exit examination for grade 12 learners, there is clear concern for the general state of Mathematics, Science and Technology (MST) in South Africa. The prospects of increasing skilled labour in order to ensure a robust and growing economy is highly compromised if only 5% of the school going population are actually eligible to follow subject streams like Physical Science. The number of candidates who sat for the HG examination seemed to have increased yet that went hand-in-hand with a general decline in the matric HG Physical Science pass rate as is evident in Table 1.1. This points to the fact that the National Strategy for Mathematics, Science and Technology Education could not successfully identify the contributing factors for the low uptake and pass rate of MST in schools.

Table 1.2 below shows the number of learners passing Physical Sciences from 2008 to 2014. The split between 2007 and 2008 happened because the class of 2008 was the first to write the National Senior Certificate (NSC), a school leaving certificate in South Africa that was phased in as a result of a curriculum change in 2006. Replacing the higher and standard grade benchmark, all learners who enrolled for Physical Science now wrote the same standardised examination.

Table 1.2 Number of learners who passed Physical Science 2009-2014 (Dept. of Education)

2008	2009	2010	2011	2012	2013	2014
119 823	83 356	98 260	96 441	109 918	124 206	102 742
55%	36.8%	47.8%	53.4%	61.3%	67.4%	61.5%

Table 1.2 indicates how poorly grade 12s performed with the implementation of the new curriculum. The last three years shows a stabilisation in the pass rate in the vicinity of 60%. However, what is not immediately evident in Table 1.2 is the fact that the number of significant passes still remains alarmingly low. Table 1.3 below summarises the Physical Science statistics of 2008 to 2013.

Table 1.3 Passes for Physical Science (2008-2013) adapted from Institute of Race Relations report 2014 (Institute of Race Relations, 2014)

Subject	**Year**	**Entered**	**Wrote**	**Fail 0 – 29%**	**Pass 30 – 49%**	**Pass 50 – 69%**	**Pass 70 – 100%**
Physical Science	2008	229 934	217 300	45.1%	39.9%	11.6%	3.4%
	2009	224 908	221 103	63.1%	26.8%	8.2%	1.9%
	2010	210 168	205 346	50.5%	31.0%	12.3%	6.2%
	2011	184 052	180 585	44.7%	34.8%	13.9%	6.7%
	2012	182 126	179 201	38.6$	37.0%	16.7%	7.6%
	2013	187 109	184 383	32.6%	41.9%	18.1%	7.4%

It is a cause for great concern that the average percentage of learners who manage to obtain between 70 and 100% for Physical Science during the period 2008-2013 remains a mere 4.7%. Looking comparatively at the overall number of grade 12 learners passing Physical Science during the 2002-2007 and the 2008-2014 periods, it is therefore a fair assessment to make that, despite the many interventions (NSMST, three curriculum changes), more than ten years later, the majority of learners still find Physical Science incomprehensible. Considering the fact that the results reflected in Table 1.3 included learners who could have obtained a pass mark for Physical Science that is as low as 30%, it is fair to conclude that the quantity and quality of passes in Physical Science is yet to improve.

Researchers attribute the poor results displayed in the NSC to teacher qualifications and availability of resources (Makgato, 2007). Language, as a medium of instruction, is also identified as a crucial contributor to learner inability to perform well in Physical Science (Howie, 2003). The researcher is in agreement with Wong-Fillmore (1986; as cited in Probyn, 2005, p. 1859) who pointed out that content and language learning can be apposing goals unless there is awareness to constantly accommodate both. Unless the learning demands on the learner to understand the language of school science and the meaning of ordinary English words used as science words is emphasised, a mere focus on the language of learning and teaching (LoLT) will only serve to distract (Oyoo, 2012).

1.3 English proficiency or home language teaching?

Like most previously colonialised African countries, South Africa has inherited the English language from its colonial masters and now English has become the language in which most of the learning and teaching in South African classrooms is taking place. English is spoken at home by 7% of learners in South Africa yet it is the LoLT of 81% of learners from grade 4 onwards (Department of Basic Education, 2010). South Africa is a multilingual society with English being a third or fourth language of the majority of learners in South African classrooms. Ringbom (1987; as cited in Setati et al., 2002, p. 129) describes a first or second additional language (FAL) as a language that is spoken in the immediate environment of the learner. Ample opportunity exists and is provided to read, speak and think in that particular language. A foreign language, according to Ringbom (1987; as cited in Setati et al., 2002, p. 129) is considered a language that the learner has very little opportunity to use in natural communication situations. It is most often only encountered in a learning environment. Given the above consideration, it is fair to argue that the average learner is being taught in a Foreign Language Learning Environment (FLLE) and that rural learners hear English less often than their urban counterparts (Setati et al., 2002). This background has resulted in the current debate where researchers (eg. Brock-Utne, 2003; Howie, 2003; Kamwendo, Hlongwa, & Mkhize, 2014) and teachers alike are proposing home language as LoLT as the likely route to follow in order to improve learner performance in school subjects. Howie (2003) concluded that proficiency in English predicted success in Mathematics. Kamwendo et al. (2014) consider the inclusion of isiZulu as a LoLT, not only necessary but also viable.

It is indisputable that a level of proficiency in the LoLT is important to ensure that learners are able to benefit from the teaching that they are exposed to. However, the researcher is of the opinion that caution needs to be exercised when identifying the role that language plays in learners' poor performance in subjects like Mathematics, Science and Technology (MST).

The reasons are twofold. Firstly, difficulty with MST is not only reported for English first additional language learners (EFALs). As early as 1972, Gardner (1972; as cited in Oyoo, 2007, p. 232) conducted research on English language speakers' (from here on referred to as English home language learners (EHLs)) understanding of science words and concluded that learners generally struggle with the meaning of words when they are used in a science context. Secondly, some of the best performing countries in the TIMMS (2003) test, such as Singapore, use English as the language of instruction yet it is not the home language of the majority of learners in the country. Fellow African countries like Ghana and Botswana performed better than South Africa although English is not the home language of many of those learners. These results point to a need to seek explanations, in addition to proficiency, for the poor performance in Physical Science. Oyoo (2007, p. 231) called for a "rethinking of proficiency in language of instruction (English) as a factor in the difficulty of school science". He suggested that teachers should focus on the meaning that words assume when they are used in a science context.

The researcher will in later chapters further explore the manner in which the language of school science (LSS) uses the LoLT to convey science meaning and what teachers do or can do to apprentice learners in using LoLT to construe science meaning.

1.4 Rationale: Why consider the instructional language of the science teacher?

This investigation focussed on the anatomy of the Physical Science teacher's classroom language with an emphasis on the extent to which the teacher's language use is able to socialise learners into the language of school science (LSS). School science differs from science as experienced in industry yet the science discourse in school has properties that are similar to professional science discourse (Fang, 2006). The language used to communicate science in classrooms is far more authoritative, less context dependent and contains much information in a single word than is the case for everyday language use. For these reasons, LSS is such a specialised language.

The researcher is therefore of the opinion, in line with Bernstein (2000), that a more "visible pedagogy" whereby learners are made aware of the "more salient features of LSS" (Fang, 2006, p. 507) is needed. Such pedagogy will make the criteria for success in school science explicit to learners. Both English home language learners (EHLs) and English First Additional Language learners (EFALs) can benefit from a more explicit teaching of the LSS.

Flanders (1970; as cited in Oyoo, 2012, p. 851) asserted, more than four decades ago, that as much as two thirds of all the talking in the science classroom is teacher talk. Learning still happens on a social plane judged by the wide acceptance of the Vygotskian perspective on learning. Vygotsky (1978) developed the concept of a Zone of Proximal Development (ZPD) which refers to a theory of assisted learning. According to Vygotsky, learning first happens on an inter-psychological plane (social learning) and then on an intra-psychological plane (independent learning). The teacher's role in the teacher-student interaction is to mediate meaning on the inter-psychological plane. This happens mostly through the use of language. Given the large proportion of teacher talk and the historically poor performance of science learners, it is likely that a large proportion of teacher talk might be incomprehensible to the learner.

Familiar words used in a science context assume different meanings to their everyday meaning. This necessitates a focus on vocabulary teaching in the science classroom, not only for science words like *thermometer*, but also for everyday words like *volatile* that means something very different from its everyday meaning when used in a science context. Not only should teachers teach their learners to be wary of word meanings, Fang (2006) states that the language used to construct knowledge, beliefs and worldviews is distinct from the social language that learners are accustomed to in expressing everyday experiences. In a school context, meanings assigned to words are far more precise, sentences are typified for lengthy nouns and verbs are changed to nouns so that a *process* adopts the status of a *thing*. For example, literature ascribes the practice by scientists to use the word *force* as a noun to be a contributing factor why learners see *force* as a property of an object rather than an interaction between two objects (Brookes & Etkina, 2009). Science also communicates meaning, not only through language but also through symbols, diagrams and graphs. It is therefore clear that instructional language should be a carefully negotiated resource in the science classroom (Oyoo, 2007, 2012). This can be achieved if the teachers accept their dual role of science and language teacher. The learners need the teacher to steer them past the potholes contained in the LSS to ensure that they come to an understanding valued by the science community. Driver (1989, p. 482) highlights the dependence of the learner on the teachers' guidance by stating:

> Learning science … is seen to involve more than the individual making sense of his or her personal experiences but also being initiated into the 'ways of seeing' which have been established and found to be fruitful by the scientific community. Such 'ways of seeing' cannot be 'discovered' by the learner—and if a learner happens upon the

> consensual viewpoint of the scientific community, he or she would be unaware of the status of the idea.

Driver (1989) in the above statement also alluded to the sociocultural nature of learning. Teacher talk needs to be appropriate to the learning demands of the learner as well as to the learning outcomes of the particular context. An absence of such a focus will result in language serving as a barrier to learning science (Wellington & Osborne, 2001).

1.5 Problem statement

The process of negotiating meaning through language in science classrooms is complex in the sense that the language of science is not transparent and science concepts cannot mediate meaning by themselves irrespective of language use (Clark, 1997). As a starting point, therefore, one may consider that learning science is akin to learning a language (Wellington & Osborne, 2001). Learners are familiar with the language patterns that they have learned from everyday experiences. These patterns do not fit with the new language patterns of the language of school science (LSS). In colloquial speech, words tend to have loose meanings whereas when using words in talking science, very precise meanings are assigned to words. In everyday language, the words *mass* and *weight* are used interchangeably signalling the same thing. When talking science, very different understandings are derived when talking about *mass* and *weight*. Lemke (1990) used the example of the word *two* that can represent a quantifier in one case and a classifier in another. In answering the question “How many electrons?” a simple response “two” (cardinal number) will be acceptable. The same response to the question “Which orbital?” would not have been satisfactory as it is important that the orbital needed to be specified, for example, “2 P” (ordinal number).

A compounding factor to learning the LSS is the fact that it employs everyday language (e.g. English) to communicate its meaning. Familiar words used as science words obtain new and different meanings when used in a science context (Oyoo, 2012). Strömdahl (2012) pointed out that the process of obtaining the new meaning is “constrained by existing meanings and references” (p. 55). Hence, a constant monitoring by the teacher is necessary to ensure that no blending between common sense understandings and science understanding exists.

English home language learners may assume the understanding of a word used in a science context only to find that the meaning is no longer the same due to the changed context. The situation gets compounded for EFALs as they experience difficulty on multiple levels. They need to learn the language of science through a language medium that they are not familiar with within a culture that might contradict their own.

Unless teacher instructional language raises awareness of the *polysemous* nature of science words and their dependence on *context* for meaning, learners will be unaware of the changed meaning of these familiar words. They may be unable to understand how science meaning is construed through language in an absence of explicit teaching of the features of LSS. Learners will therefore continue harbouring views about the physical world that are in contrast with those held by the scientific community and, as a result, be unable to perform on grade level.

1.6 Research aim

The aim of this research is to evaluate teachers' instructional language for awareness that

- familiar words that assume different meanings in the science classroom can hinder learners' understanding of science concepts
- vocabulary building is important in the science classroom
- the language of school science is a specialised language and teaching the features of this language is part of teaching science
- effective teaching of the LSS and LoLT simultaneously might be necessary for some learners.

A reflection on the successful uptake of opportunities provided to learners by the teacher to practice their newly acquired skill (talk to learn) does not fall within the scope of this research.

1.7 Research questions

The researcher will answer the following questions with regard to the teacher's instructional language:

Research question 1:

> Given the polysemous nature of words, is there evidence of Physical Science teachers' awareness of the potential for confusion that the technical and non-technical words in a science context pose in the science classroom?

Research question 2:

Do teachers consciously endeavour to teach towards establishing a common understanding amongst learners and the science community?

Research question 3:

Do teachers provide a pedagogy that scaffolds language learning and learning through language?

1.8 Chapter Summary

In this brief chapter, the researcher provided an introduction, effectively an orientation to the study. It was argued that a focus on the language use of Physical Science teachers could resolve the persistent and consistently low performance in Physical Sciences in South African secondary schools. The report is structured as follows:

Chapter 1

An introduction, background, rationale, problem statement, research questions and the outline of the research report was discussed.

Chapter 2

In this chapter, a brief discussion of the theoretical and conceptual framework that guides this study is provided. A report on the literature that (a) provides evidence of the difficulty of science words; (b) describes teachers' classroom language as a resource to facilitate "new ways of seeing"; and (c) investigates how teachers assist science learners in a science classroom in general and in the South African context in particular.

Chapter 3

A report on the research methodology and design used for this particular study is provided. A discussion on the ethical considerations is also part of this chapter.

Chapter 4

Reporting on the data analysis conducted on the data collected through observation and interviews.

Chapter 5

A discussion of the results obtained during the research.

Chapter 6

A summary of the conclusions drawn and recommendations are made for future studies.

2 Chapter 2

Literature Review

2.1 Introduction

In this chapter, a brief discussion of the theoretical and conceptual framework that guides this study is provided. The literature review (a) provides evidence of the difficulty of science words; (b) describes teachers' classroom language as a resource to facilitate new "ways of seeing" (Driver, 1989); and (c) investigates how teachers assist science learners in science classrooms in general and in the South African context in particular.

2.2 Theoretical Framework

Vygotsky's socio-cultural perspective on learning places the teacher, or a knowledgeable other, central to the learning process. The teacher establishes what Vygotsky (1978) called a "zone of proximal development" (ZPD) which is the meaning potential which a learner can achieve with the assistance (scaffolding) of the teacher. Within this framework, science teaching and learning is a social event aimed at enculturating the learner into the science community. According to Vygotsky (1978), the learner will first learn on an intra-psychological plane which could be the whole class interaction, the teacher-learner or the learner-learner interaction that may occur in classroom situations. Eventually, learning happens on an inter-psychological plane where the learner is able to apply the new knowledge without assistance from others.

This scaffolding fits well with the notion of the peripheral participant which Lave and Wenger (1991) use to describe the apprentice in any community of practice. The teacher could very well fulfil the role of knowledgeable other who, by modelling the practices of science, enculturate the learner in these ways of seeing. The researcher is of the opinion that enculturation should occur through language and other semiotic practices employed in science teaching.

The language of school science (LSS) is generally overlooked in the science classroom and focus is normally given to the opportunities that teachers provide for learners to do science (Oyoo, 2012). However, practical work in itself makes use of language to communicate intentions or report findings. A theoretical framework that gives language centre stage in any learning activity is that of Systemic Functional Linguistics (SFL). SFL is a theoretical framework developed by Halliday (1993). It is concerned with language as a source of meaning and considers the functions of grammar in creating and expressing that meaning (Halliday & Matthiessen, 2004). An SFL perspective sees language as functional, the primary function being to convey meaning. However, the meaning conveyed is context bound. The process of language use is semiotic, that is, the choice of words is influenced by the context of a situation.

Figure 2.1 below represents how Halliday (1993) perceives the model of SFL. He identifies "field" (topic or focus of activity), "mode" (whether language is spoken or written) and "tenor" (relationship between participants) as the three variables of the register of a specific discipline. Register refers to "a cluster of associated features having a greater-than-random tendency to co-occur" (Halliday, 1988, p. 164).

In the case of the lessons observed, "field" refers to the discipline of Physical Science and the specific topics discussed during the lesson observation. This will also include the vocabulary used by the teacher. Eggins (2004) indicates that "field" varies along a continuum of technicality from highly specialised to everyday knowledge. The "mode" was mostly spoken language but the researcher will point out that, due to the specialised nature of the language of school science (LSS), the language used resembled more that of written text. The teacher in both classrooms observed assumed the role of knowledge bearer, Teacher A more so than Teacher B. The "tenor" was therefore mostly declarative. It should therefore be clear that field, mode and tenor are the three components most influenced by context.

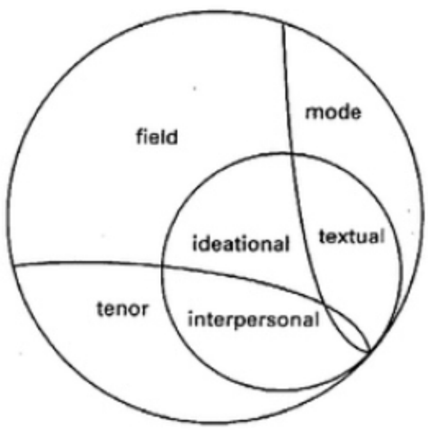

Figure 2.1 Systemic Functional Linguistic Model adapted from Halliday (1993)

Associated with each component of register, Halliday (1993) identified modes of meaning referred to as meta-functions – interpersonal (social reality), ideational (physical and biological reality real world meaning – meanings of how we represent reality in life) and the textual (semiotic reality). Field is realised through the patterns of process, participants and circumstances. These are the elements of ideational meaning. Tenor is realised through mood (declarative, interrogative). Resources are used to communicate attitudes which are elements of interpersonal meaning. Mode is realised through theme. Textual meaning is achieved by foregrounding and backgrounding information, nominalisation and cohesion of text.

Finally, SFL views language as a semiotic system, i.e., "language is as it is because of the tasks it is asked by its users to perform" (Kress, 2001, p. 11). The strength of SFL in this study is that it provides "an analytical methodology which permits the detailed and systematic description of language patterns" (Eggins, 2004, p. 21).

Understanding the functional meaning of linguistic resources strengthens an analysis of language development and use. This is achieved by combining the meaning-making that is fundamental to language development with an understanding of the structures through which meaning is realised. Teachers may be unaware that what they say might be interpreted differently by learners due to the influences of everyday language that are, in many cases, contrary to academic language. An SFL approach creates a greater awareness of language and allows teachers to enable learners' academic language development without compromising their conceptual understanding of science concepts (Schleppegrell, 2004).

2.3 Conceptual framework of the study

Teacher classroom language in this research includes both the language of school science (LSS) and the language of learning and teaching (LoLT). LSS is the language that teachers use to convey science. Nagy and Townsend (2012) refer to this language as academic language, Martin (1993) called it scientific English. In short, LSS is the language that learners need to access academic texts. It has a closer resemblance to written language than spoken language. For this reason, many of the language difficulties considered in this report are the same as those found in written language.

Figure 2.2 below represents the conceptual framework of the study. The teacher's classroom language plays the important role of enculturating learners into the LSS by employing LoLT (English) to construe science meaning. LSS being such a specialised language, uses LoLT in unfamiliar ways, hence, with regard to LoLT, it is important to consider both English Home Language Learners (EHLs) and First Additional Language Learners (EFALs) and how they experience LSS in the process of deriving meaning in a science classroom. LSS entails vocabulary and grammar. Amongst others, the vocabulary can be everyday words that are used in a science context (words in science) or everyday words that represent science concepts (science words). Teachers need to categorise words as either in order to decide how best to assist learners with the understanding of these words. When focusing on grammar, teachers have a choice to focus on form, i.e., whether words are nouns or verbs or on the meaning that is conveyed by particular grammatical choices. The latter is the focus of systemic functional linguistics. The construction of the grammar conveys specific meaning. The teacher is assigned the role of knowledgeable other and will primarily use language to facilitate the teaching and learning process.

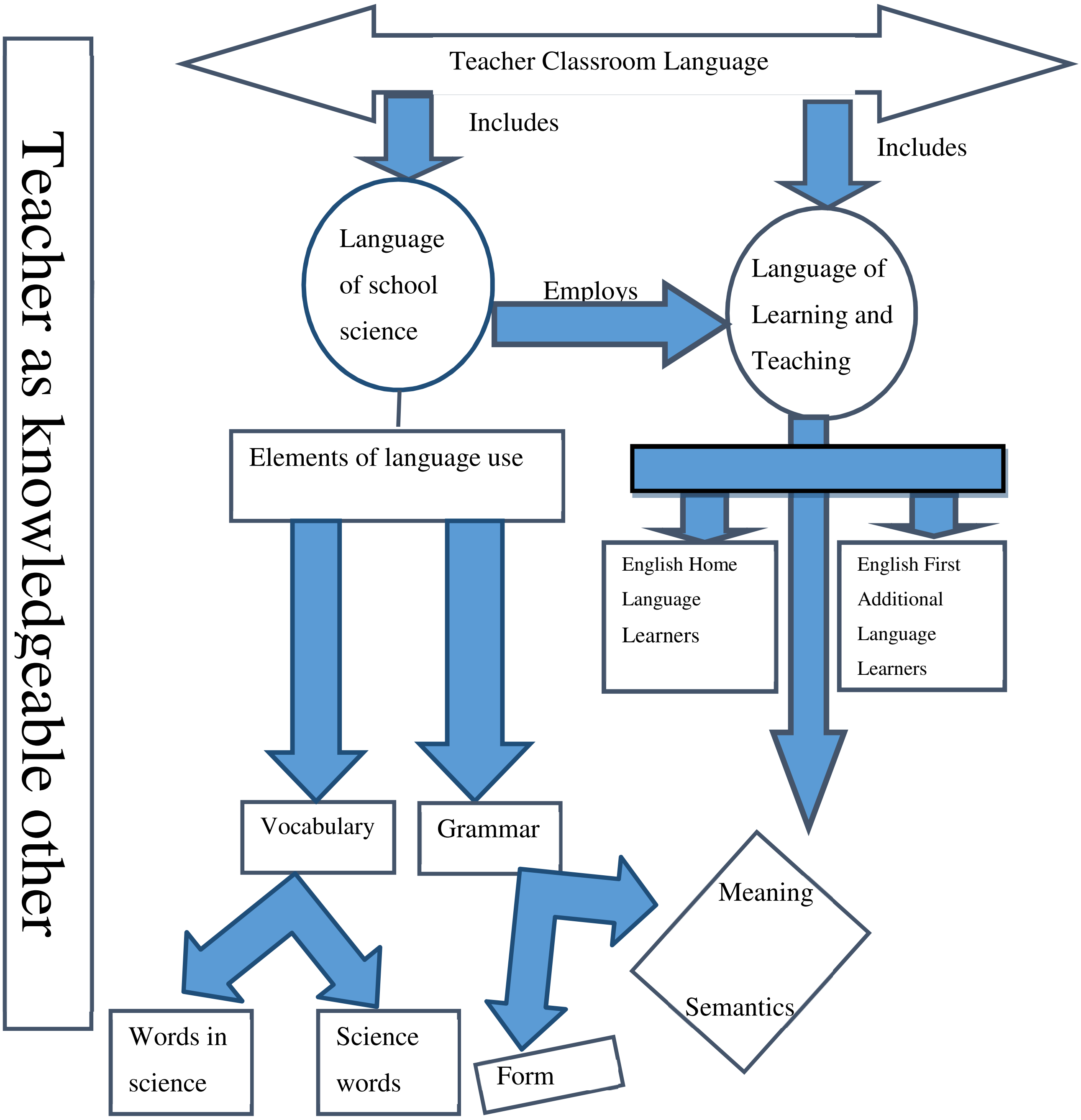

Figure 2.2 Conceptual framework of the study

2.4 Evidence of the general difficulty of science words

> *The study of vocabulary is at the heart of language teaching and learning, in terms of the organization of syllabuses, the evaluation of learner performance, the provision of learning resources, and, most obviously, because it is how most learners see language and its learning difficulty* (Carter, 1988, p. vii).

Figure 2.3 below is a representation of a categorisation of science vocabulary. Science words can be divided into two components, a technical and non-technical component (Oyoo, 2007). A word is categorised as *technical* when it is used as a concept in Physical Science and *non-technical* if it is part of the vocabulary and usage of everyday English used in a science context (Tao, 1994). The non-technical component refers to *non-technical* words *in the science context*, *meta-representational terms* and *logical connectives*.

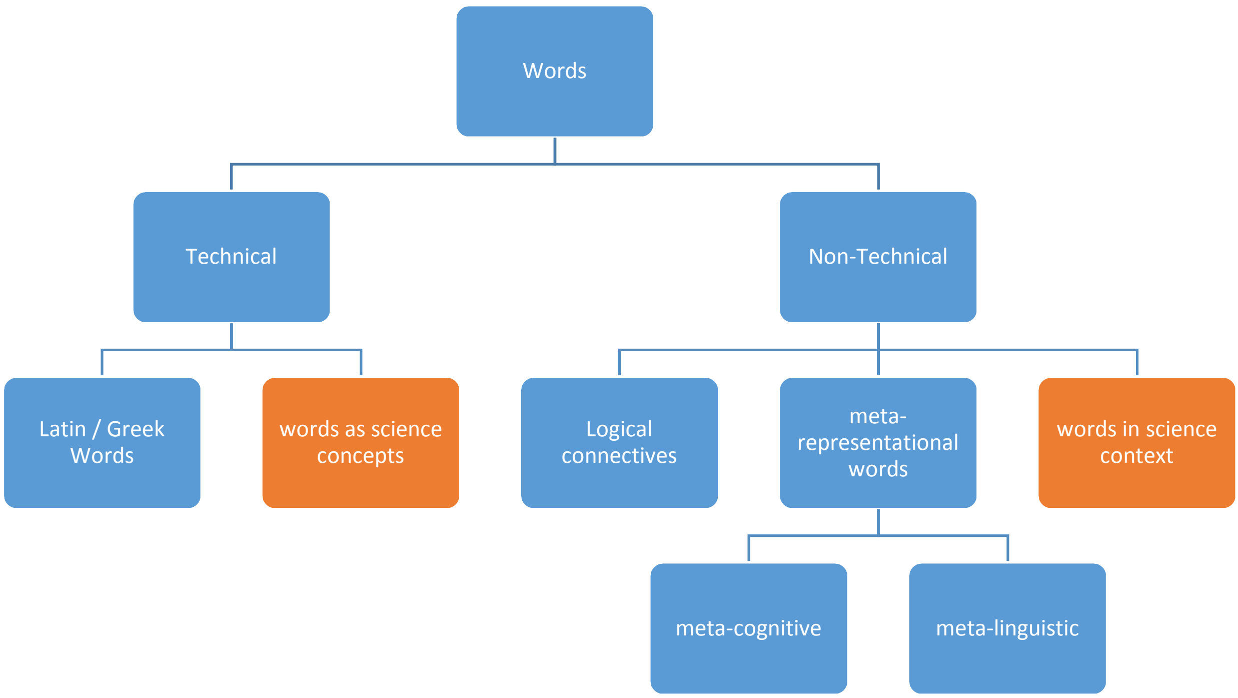

Figure 2.3 Science Vocabulary

Research has shown that all non-technical terms pose difficulties for science learners (Wilson, 1999). *Logical connectives* and *Meta-representational* words will only be briefly discussed in 2.4.2 and 2.4.3 respectively. A *naked* flame, *liberated* gas or *retarded* molecules create unfamiliar contexts which most learners are not used to. The words *naked*, *liberated* and *retarded* are examples of non-technical words labelled as *words in science context* in figure 2.3 above.

Most teachers of science realise that a technical word like *myopia* is unfamiliar to most of their learners. These words are explained meticulously in most science classrooms when introduced for the first time. This may be that the Greek or Latin origin of these words remind teachers of their own unease with the unfamiliarity of these words. However, very few teachers seem to be aware of the difficulty caused by the familiar technical words like *mass, force, impulse* and *momentum* that assume unfamiliar meanings and strange contexts (Osborne, 2002) when used in the science classroom. These technical words are labelled as *words as science concepts* in figure 2.3.

Of interest to this study are the two categories of words, namely, *words in a science context* and *words as science concepts*. The difficulty of these words lies in their polysemous nature, i.e., the same word can assume different meanings depending on the context in which it is used. The everyday context in which learners might have encountered these words (*naked*, *liberate, retarded*, *mass, force, impulse* and *momentum*) might lead to an understanding that is contrary to that of scientists.

In science education, interest in word understanding first gained momentum when Gardner (1972) conducted a study for the Australian Science Education Project on over 600 non-technical words considered to be essential for studying science. The following sentences are examples that Gardner (1972; as cited in Oyoo, 2012, p. 852) used to illustrate non-technical words used in a science context: "gas molecules display *random* motion; we may *predict* their behaviour from *theoretical* considerations; the actual *volume* of the molecules may be *neglected*". For each word, a multiple choice question was prepared and the tests compiled were administered in 39 schools with large samples of students. From the results, Gardner compiled vocabulary lists of words accessible to learners at different stages in secondary schools (Farrel & Ventura, 1998; Tao, 1994). Gardner (1972) found that most words used by school teachers in classrooms whilst teaching science simply were not clear to their learners.

Cassels and Johnstone (1980, 1985) tested each of the non-technical words in four contexts namely, synonym, sentence, science and non-science contexts, to investigate if comprehension of the words was context-dependent. They found that, for each of the 95 words tested, students' performance varied among the contexts which showed that the majority of learners had considerable difficulty in recognising the correct scientific usage for a number of words (Osborne, 2002).

This research was repeated in similar form (Farrel & Ventura, 1998; Marshall & Gilmour, 1990; Oyoo, 2008; Pickersgill & Lock, 1991; Prophet & Towse, 1999). Farrel and Ventura (1998) found that both first and second language learners struggled with the non-technical words in a science context. EFALs tended to struggle more than their first language counterparts but there were exceptions to this (Marshall & Gilmour, 1990). Gender had no effect on word understanding (Oyoo, 2008); EFALs may have encountered the non-technical words used in a science context for the first time in the science classroom and there was a positive correlation between a student's score on a verbal reasoning test and on a test of comprehension of non-technical words (Pickersgill & Lock, 1991).

A similar study was conducted in South Africa by G. Jacobs (1989) in which she tested word understanding of first year physics university students. The results were in line with those of previous research. She considered this alarming since these words are regarded "common currency" by university teachers and, secondly, "all of the students had to have studied physics at school" (Jacobs, 1989, p. 397). Jacobs' findings confirm that difficulty with word understanding is also applicable to the South African school context. Farrel and Ventura (1998) replicated Jacobs' 1989 study for their students in Malta and came to a similar conclusion.

Following is a closer look at three aspects of science vocabulary, namely, *polysemy*, *logical connectives* and *meta-representational* words that are reported as being responsible for the difficulties in developing learners' science understanding.

2.4.1 Polysemy and context

Science words are polysemous. Trimble, 1978 (cited in Farrel, 1990, p. 37) describes polysemous words as "words that have one or more general English meaning and which in technical contexts take on extended meanings". Deane (1988) describes polysemy as "multiple but related meanings for a single form" (p. 325). Table 2.1 below represents the two definitions of polysemy on a continuum with Trimble's on one extreme end where a word form can have science and everyday meanings that are widely removed from each other almost as in the case of homophones, where the sound is the same but form and meanings are different. Deane's description fits into the opposite end of the continuum of polysemous words where a word in everyday and science contexts will have different but related senses. Below are examples of the latter as discussed by Farrel (1990),

> For example, current in the technical sense of a flow of electricity may be linked with its general reference to a flow of water. The general meaning of the word resist may be linked to its technical sense of obstructing, or slowing a flow of electricity. Capacitor may be explained by its 'capacity' to store electricity (p. 37).

Table 2.1 Continuum between Polysemy and Homonymy

Phenomenon	Meaning Relatedness	Science word	Everyday context	Science context
HOMONYMY POLYSEMY	None	Force	Violence	Interaction between two or more objects that can be cause for a change
	Close	Current	Flow of water	Flow of electricity

Haglund, Jeppsson, and Ahrenberg (2014) reported that "our everyday intuitions of motion and interaction of physical objects fit well with how physicists use the term momentum" (p. 1). A pedagogical implication is that teachers could use this familiarity from everyday experience and develop the understanding until it is in line with a science understanding of momentum by considering the linguistic challenges that accompany learning.

It is unfortunately not always the case that the everyday sense of a word could be used to aid understanding of the more technical meaning assigned to a word when used as a science word. Some words only share vague meanings with their everyday meanings (Farrel, 1990; Haglund et al., 2014). Table 2.1 above shows how the science meaning of the word *force* differs from an everyday understanding. In the science classroom, *force* is described as an interaction between two or more objects that can cause a change to one or all objects involved. The changes could be in the shape, direction of movement or acceleration of an object (Siyavula, 2012). Everyday understanding of the word *force*, amongst others, is *strength*, *power*, *impetus*, *violence* or *intense effort* (Farrel, 1990, p. 38). It will be very difficult for any teacher to use the everyday understanding as a premise from which to guide the learner to eventually adopt the science meaning. The word *power* has its own specialised meaning unrelated to a *force* when used in science context. Haglund et al. (2014) attribute the erroneous conclusion that an object that moves at constant velocity must experience a force in the direction of motion to learners' everyday understanding of the meaning of the word *force*. It is clear that an explicit focus on the language use of the teacher is required to ensure that the learner eventually adopts the science understanding of words like *force*.

The language of science gives meaning to words in context which differs from their everyday (English) meanings. If familiar words obtain unfamiliar meanings due to the changed context, learners fail to understand the accepted meaning of these words. The everyday context that learners use to conceptualise concepts is mostly inadequate to reach the conceptual understanding shared by the scientific community.

An absence of a focus on the polysemous nature of words will result in the classical example from Johnstone (1991, p. 80) that will serve as a last case in point.

> 'Volatile' has left the realm of science with its meaning of 'easily vaporized' and gone off into common speech where it is applied to markets, people, countries and hostile situations. It then filters back into science with meanings which do not seem out of place in science (to the pupils) but which make a nonsense out of a science discussion. A 'volatile compound' is understood as a 'flammable, explosive, unstable and dangerous compound'. If the teacher asks, Do you know the meaning of volatile?' he will be assured by his pupils that they do, but the vital check that they are using the same meaning may not be carried out."

2.4.2 Logical connectives

The science language also makes frequent use of logical connectives which are words and phrases which serve as links between sentences or between a clause and either a phrase or another clause in a sentence. Gardner (1972) found 75 connectives proven to be problematic for 15-year-olds. Science text, however, commonly employs these to improve readability. Maskill (1988) reports that students tend to interpret the word *conversely* as having the same meaning as the word *because* since that is a more familiar relationship to them. This research will not focus on logical connectives.

2.4.3 Meta-representational words

Meta-representational words are words that are used to say (metalinguistic) or words that are used to think (metacognitive). In science, examples of metalinguistic words could be *describe*, *define* or *explain*. Examples of metacognitive words are *infer*, *calculate* or *deduce*. Wilson (1999) studied the meta-representational words used by five teachers in six upper-secondary chemistry classrooms across sixty-nine lessons. The finding was that "...word use was generally limited in extent and simple or colloquial in expression, and the language of the enacted curriculum did not match the terminology of the official curriculum document" (Wilson, 1999, p. 1067). The absence of words which refer to different types of thinking (metacognitive), and expression of ideas (metalinguistic) is an indication that teachers fail to direct their learners' attention to alternative forms of thinking (multi-semiotic mode) and expressing thoughts through the use of different words with subtle distinctions in meaning.

2.5 Approaches to vocabulary building

> *Words are learnt not as in a dictionary but as in a thesaurus, each one being progressively located, in the expanding topological space, by reference to the 'others' to which it is taxonomically related* (Halliday, 1993, p. 99).

Haug and Ødegaard (2014) equate conceptual knowledge to highly developed word knowledge. They say that conceptual understanding will not be achieved if teachers simply rephrase learners' answers without clarifying the changes s/he is making to the attempts made by these learners. An absence of these practices normally signifies an instruction preference that focuses on knowledge transmission.

Thompson and Rubenstein (2000) suggest entomologies or word origins as a strategy to aid vocabulary building. They demonstrated their point with the word *perpendicular* with its origins from the root *pend*, which means *to hang*. A string which hangs freely is perpendicular to the ground. Learners are therefore afforded an opportunity to use their everyday knowledge in the science classroom if they are asked to come up with English words with the same root. The idea of relatedness (Cervetti, Pearson, Bravo, & Barber, 2006) of words originated from Sutton (1992) who suggested "cognitive mapping" whereby a word is hooked onto another and gaining more connections represents an enrichment of meaning. Only some of the connected words are selected for a specialised meaning in a particular context. In short, effective vocabulary instruction requires multiple exposures in meaningful contexts. Bravo et al. (2006) suggest the following elements as essential in any process of vocabulary building:

- Targeting a focused set of science words
- Providing multiple exposure to science terms through multiple modalities
- Systematically and explicitly introducing terms in a semantically networked way
- Making connections between targeted words and words students already know.

Figure 2.4 below represents a synthesis of approaches from Bravo et al. (2006) and Thompson and Rubenstein (2000) which serves as a suggestion for assisting with vocabulary building. Most teachers target a focused set of technical words when teaching a science topic.

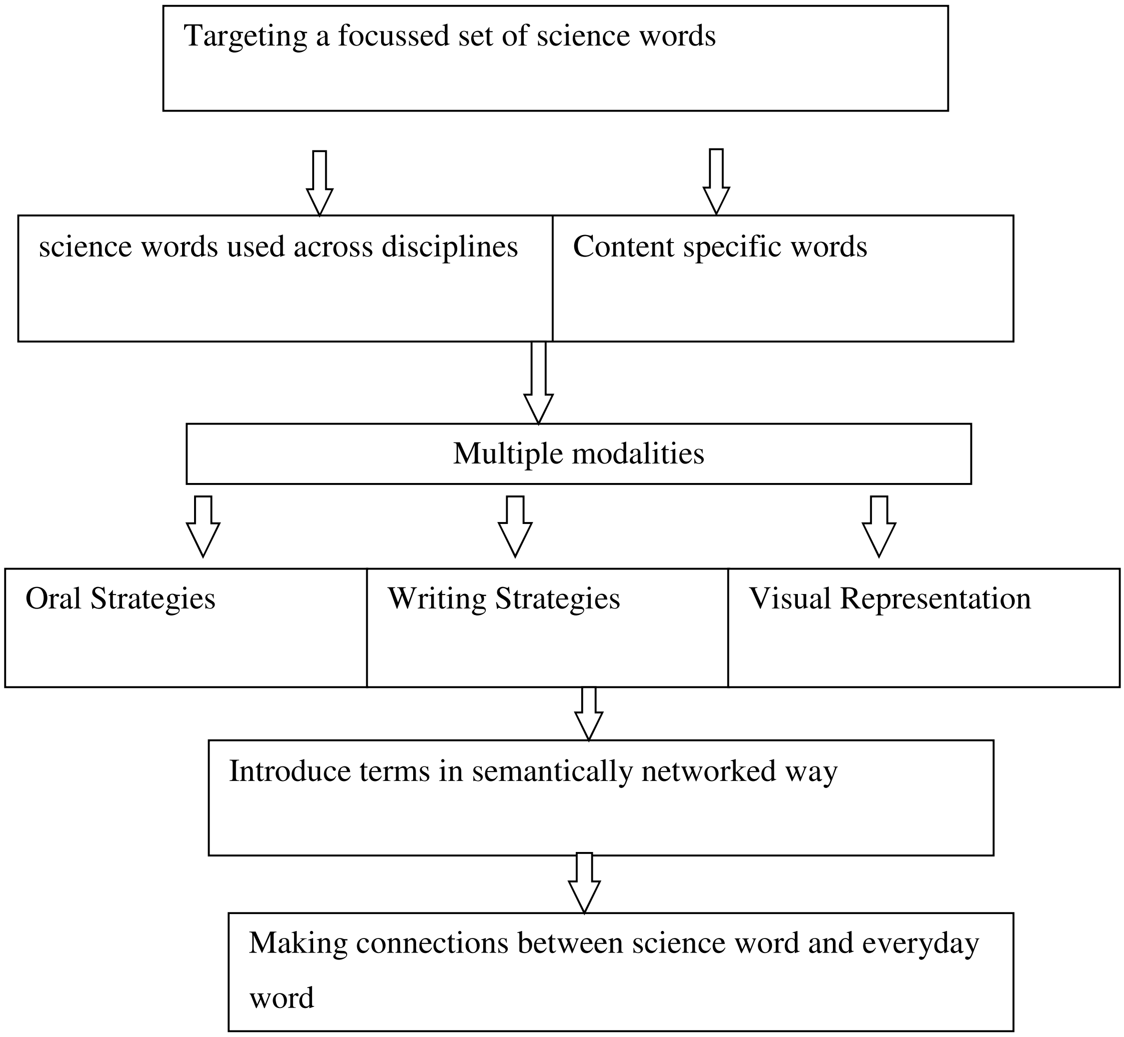

Figure 2.4 Approach to vocabulary building (Adapted from Bravo, Cervetti, Hiebert, and Pearson (2006) and Thompson and Rubenstein (2000))

Very few teachers consider the possibility that those words could be used across disciplines without carrying the same meaning into those different disciplines. Figure 2.4 above suggests a categorisation of the words used as either across disciplines or content specific. In so doing, teachers can alert learners of the changed meaning should it occur. To ensure conceptual understanding, learners must encounter words in different modalities. Thompson and Rubenstein (2000) identified, amongst others, oral, writing and representational strategies as a means through which teachers can assist with vocabulary building. Although these suggestions were made for Mathematics, the researcher is of the opinion that it would work equally well for developing a science vocabulary. Bravo et al. (2006) suggest that words should be semantically connected when introduced. In other words, learners need to know the network of words usually used in conjunction with the given word. This is the opposite of knowing words on a definitional level only where learners are unable to use words to build conceptual themes. Linking words to their everyday meaning in this model creates awareness amongst learners that the changed context results in a different meaning.

2.6 General difficulty of the science language

> *Adults may choose to deny it, but children in school know very well that there is a 'language of science'* (Halliday & Martin, 1993, p. 2).

The average learner can recognise the language of school science (LSS) as different from everyday conversational language. It is more difficult to pinpoint exactly what those differences are and more so to emulate that manner of speech. Most learners will attribute the difficulty to the number of unknown words present in one sentence sometimes referred to as "jargon". However, being able to speak the language of science goes beyond the development of a comprehensive vocabulary. It involves understanding how and why the grammar has been construed in a particular manner. This is the focus of a Systemic Functional Linguistic (SFL) theory analysis (Halliday, 1993). SFL theory analyses language in terms of the function it serves and the meanings it conveys in a given social context. This view creates awareness in the teacher of the reasons they use language in a particular manner and the different meanings that result because of that choice. It is an important role of the science teachers to assist the learners to be able to develop language as a semiotic tool essential for demonstrating knowledge as well as a means of social enculturation into the science community. Bernstein (2000) refers to this as a visible pedagogy whereby teachers make the criteria for success in school science explicit to learners.

Schleppegrell (2007) supports pedagogical practices that develop content understanding through a focus on the linguistic challenges contained in the manner in which LSS is used. She argues that learning science is learning a language hence consideration of how the LSS is used to construe certain meanings needs to be taken into account when teaching school science. Language can be employed in the following three ways to construe meaning as stated by Young and Nguyen (2002, p. 7), namely, (1) the means by which physical and mental reality is construed in the texts; (2) the degree of abstractness or concreteness of the texts; and (3) the rhetorical structure of scientific reasoning that the texts demonstrate. This research focused on the first two ways in which meaning is communicated through text. Considering the degree of abstractness or concreteness of text (textual meta-function), a discussion of several ways in which meaning is condensed in scientific discourse follows below.

2.6.1 Dense noun sentences

Halliday and Martin (1993) pointed out that one cannot separate the language from the subject matter itself because science is defined by the discourse it uses. One of the major differences between everyday language and science language is the lexical density of the science language. Lexical density is conventionally measured as the ratio of content words over total words (Nagy & Townsend, 2012). An alternative way of looking at the complexity of text is to calculate the ratio of the number of nouns to the number of clauses in a text. In both cases, the words that refer to content or factual knowledge in one sentence tend to be comparatively higher in scientific speech than everyday speech. This is the case since a larger number of nouns are used to depict actions and events which are usually represented by verbs in everyday speech (Unsworth, 1997). The following from Martin (1993, p. 258) is an example of typical science text: "Their ***ability*** to conduct **electricity** is intermediate between **conductors** and **insulators**".

2.6.2 Grammatical metaphor

This is the substitution of a grammatical class, or one grammatical structure, by another (Halliday & Matthiessen, 2004). Martin (1993) drew the distinction between a lexical and a grammatical metaphor in that the former experiences a transformation of the word whereby the latter is a transformation of the grammar. A lexical metaphor for **a troubling situation** is generally referred to as **a thorny situation**. The word **troubling** has undergone a transformation to the word **thorny**. Changing the word **refract** to **refraction** is a transformation of the same word from a verb to a noun. More importantly, as Painter (1999) states, in a grammatical metaphor, the meaning does not match the typical linguistic form for that meaning. Therefore, **refraction** represents a *thing* but to **refract** is actually a *process*. It can be appreciated that grammatical metaphors contribute to the high lexical density so common in science text.

2.6.3 Nominalisation

Nominalisation is a kind of a grammatical metaphor; it builds abstractions, generalisations and arguments. They allow scientists to construct hierarchies of technical terms, to expand the meaning of things via numbering, describing, classifying, and qualifying them, and to synthesise previously stated information so that it can be taken up for further discussion in the text (Fang, 2006). Nominalisations are verbs that have been re-construed as nouns, such as *erosion* (erode), *evaporation* (evaporate), and *growth* (grow) (Avenia-Tapper & Llosa, 2015). Once an event or a quality has been turned into a thing, it can generally be counted. The example of the noun *growth* from the verb *grow* is a case in point. Represented as a verb (to grow) there are limited ways for describing the process *to grow* but, once changed to a noun, *the growth*, there is so much more that can be done mathematically with the word. Examples are *the growth rate, comparing growth rates* and *a change in growth rate*s. This linguistic feature allows us to represent processes as things.

However, nominalisation is not only a word-level phenomenon but also a syntactic phenomenon. Verbs and adjectives are turned into nouns so they can serve as the head of a noun phrase that expresses a proposition, that is, information that would typically be expressed by a complete sentence (e.g., They evaluated the program > Their evaluation of the program; The package was heavy > The heaviness of the package). Nominalisation is also one of the more difficult aspects of academic language and is, according to Halliday (1988), acquired much later.

A clause can consist of a noun (common noun) preceded by various word items that all characterise the common noun. These words form a nominal group or noun phrase, i.e., they are also nouns but distinct from the common noun in the role that they play with respect to the common noun. Part of the difficulty of nominalisation is that it encodes multiple meanings in a noun phrase (Young & Nguyen, 2002). To ensure that learners understand teacher speech, these meanings need to be unpacked in order to arrive at the common sense meaning. Schleppegrell (2004) asserts that “new ways of using language lead to new ways of thinking and new forms of consciousness in students” (p. 18). The lexical dense sentences brought about through nominalisation contain information that might be hidden from learners unless teachers are able to equip learners to unpack these nominalisations by modelling the practice.

2.7 Teaching towards a “new way of seeing”

> *[T]heoretical models … will not be ‘discovered’ by children through their practical work … guidance is needed to help children assimilate their practical experiences into what is possibly a new way of thinking about them* (Driver, Asoko, Leach, Scott, & Mortimer, 1994, p. 49).

Considering how text construes the physical world (ideational meaning), Halliday and Martin (1993) identified *material*, *mental*, *verbal* and finally *relational* processes as ways in which text represents the physical world.

Relational processes have two obligatory participants where one either defines the other or represents an attribute of the other. The following is an attributive clause: "*All metals conduct electricity*". Schleppegrell (2007) describes an attributive process as constructing information about membership to a class, i.e., a part-whole relationship. In the example given, the class is that of metals and an attribute is its ability to conduct electricity. Should learners be able to recognise attributive clauses, then they will also be able to tell that they are not reversible (passive). In other words, learners are less likely to interpret the above statement as saying: *"If it conducts electricity then it is a metal"* (Maskill, 1988, p. 46). Maskill ascribes learners' tendency to reverse attributive statements to the fact that, unlike in everyday experience, learners just do not know enough counter examples in science to realise that their interpretation might be wrong.

Identifying clauses, on the contrary, are bi-directional since they communicate a relationship of equality. They provide a way of identifying technical terms by means of language that are, in a sense, less technical. Therefore, a statement like *"Sound is a compressional wave that can be heard"* can also be made as *"A compressional wave that can be heard is called sound"*. A common occurrence of identifying statements is in multiple choice questions where learners are expected to define technical terms. By categorising the statements that learners may encounter in the science classroom, teachers can assist learners to develop an awareness of the meanings that they can construe from such statements.

Explicit teaching of the language used in classification can be beneficial as demonstrated in the following case. The statement *"All matter can be classified as a solid, liquid or gas"* provides the following information:

- A general class = matter
- Specific states of matter = solid, liquid, gas
- Physical states of matter is only one way of classifying = can be.

Recognising the meanings they make in the texts they read does not just come naturally in learners' ordinary language development. The everyday context in which the majority of learners developed their language competency does not necessarily facilitate a smooth transfer into the scientific way of seeing. Learning in schools is done primarily through language yet the language of school tasks is seldom explicitly discussed or taught in schools. Literature advocating that learning science requires learning the language of science is in abundance and well received in the research community (Oyoo, 2012; Scott 1998; Wellington & Osborne, 2001). Learning science therefore requires socialisation into new registers through interaction with knowledgeable others that is meaningful in the new contexts where those registers are functional. Touger (1991) from a systemic functional linguistics perspective suggested that students may "… infer that force is a concrete noun (a thing or a person) and thus an agent, that is, the doer of the action, rather than the action itself …" when they hear references such as "the force acts" or "the force pulls". Brookes and Etkina (2009) share the view that teachers' language use could contribute to learners' view of force as an innate property of an object rather than an interaction between two or more objects.

Schuster (1994) demonstrated how the teacher's use of language influenced a particular learner's understanding: A picture of a ball thrown into the air was shown to a learner (Figure 2.5). At a point A in its upward movement, the learner was asked "what forces are there on the ball at A?" The learner's response indicated a force in the direction of motion (upwards). The same scenario as above was put to the learner but this time the question was "are there any other objects pulling or pushing on the ball at this moment at position A?" This time the learner identified the gravitational force of the earth and he did express uncertainty about the presence of an upward force, "only the Earth, downward … and … well … maybe your throw, but that was earlier, not now … though it's effect is still there".

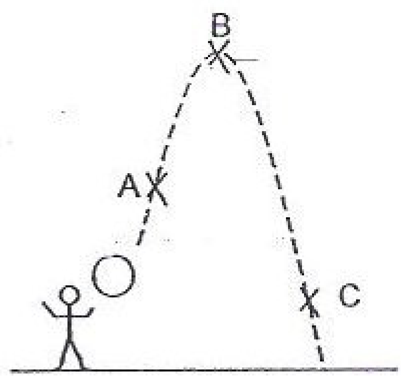

Figure 2.5 Ball thrown in the air. http://www.oldschool.com.sg/modpub/11424980044815437cc86dc

Though both questions communicated the same meaning to the teacher, the learner attributed very different meanings to each question. The second response clearly points to the fact that the learner no longer considered force as an attribute of an object, i.e., something that an object can have, as was the implication in the response to the first question. The above illustration resonates with Maskill's (1988) assertion that good teaching depends on the teacher's ability to wrap meaning up in words that will carry the intended understanding to learners. The throwing of a ball is an example of a material process. Halliday and Martin (1993, pp. 27 – 28) define verbal and mental processes as "a world of semiotic activities in which typically conscious entities negotiate meaning". These are typically realised by processes of verbal action, i.e., all words that imply saying. Examples are *ask*, *tell*, *think*, *consider*.

2.8 Multiple semiotic systems

Science classroom discourse is inherently multimodal in that scientific meanings are made through an integration of multiple semiotic systems (Tang, 2013). Hence, when doing science, learners cannot only rely on language, in order to come to the science meaning of concepts. They will have to employ symbols, oral as well as written language, and visual representations such as graphs, equations and diagrams. Kress et al. (2001) provide an insightful account of the complex and varied modes of multiple modes of representation employed by science teachers in the process of developing scientific knowledge amongst learners. Lemke's view of scientific communication as meanings made by the "joint codeployment of two or more semiotic modalities" (Lemke, 1998, p. 19) is an important observation as it cautions teachers that the various modalities of a concept cannot be placed in a one-to-one correspondence. That is, meaning made in one semiotic modality does not stand alone and cannot be made equally well in another independent from others. It is best to consider a multimodal approach as necessary in order to achieve learner understanding of science concepts.

2.9 Language needs of learners in the science classroom

> *Teachers, who understand the ideas, cannot easily pass on their knowledge since the language they must use in order to communicate contains an implicit and serious barrier to learning* (Louisa, Veiga, Pereira, & Maskill, 1989, p. 465).

Science classrooms consist of learners who are at various levels of language competency. In classrooms where the language of learning and teaching (LoLT) is not the learner's home language, the teacher has a dual task, teaching science content as well as attending to the development of learners' English proficiency level (Swanson, 2011). MacDonald (1990; as cited in Probyn, 2001, p. 251) summed the situation up as follows:

> The teachers simply do what they can in a difficult, if not impossible, situation and in the end the language proficiency of the children actually moulds the task of the teacher.

Halliday (1993) describes human learning as a process of making meaning, a semiotic process of which language is the prototypical form. Subsequently, in a learning process, the origin (ontogenesis) of language is, at the same time, the origin of learning. He continues to say that one could therefore define learning processes by the language learning and the learning through language that is present within such an episode. This view implies that the teacher should continuously focus the learning of the language of school science (LSS) as a necessary first step to learning science. This can be achieved by making it clear to learners how LoLT facilitates LSS.

Reporting on their research Chval, Pinnow, and Thomas (2014) similarly concluded that professional development that emphasises the importance of language in teaching science concepts is needed. Unfortunately, teachers often do not know how to incorporate language teaching in the teaching of science (Sutton, 1992; Wellington & Osborne, 2001).

This situation is also prevalent in the South African context. Teacher training programs seldom focus on the contribution that explicit language teaching in the classroom makes to learners' overall understanding of science concepts. Despite the language policy that acknowledges eleven official languages, English is predominantly the language of formal schooling. Teachers usually justify their use of the vernacular by arguing that many learners seldom hear English outside the classroom and hence struggle to comprehend if they are only taught in English (Setati et al., 2002).

Probyn (2001) reported that "code switching" was the most common strategy that teachers used in addressing language deficiencies when explaining concepts. Code switching is the practice by teachers to switch between the language of learning and teaching (LoLT) and an indigenous language like isiZulu or Sesotho. There are proponents both for and against the practice of code switching. Linguistic and economic constraints on home language teaching vis-à-vis the fact that adequate academic language has not been developed for most indigenous languages and the costly roll out of teaching material is not part of the scope of this research.

The researcher is more concerned about the persistent link that is forged between proficiency and the difficulty learners experience when learning science if LoLT is not the home language. It is the opinion of the researcher that such a view fails to put the language of school science at the centre stage of the learning and teaching process. A clear distinction exists between the language of school science (LSS) and LoLT whereby LSS communicates the science content and it employs LoLT (English) to construe that meaning. The same LoLT in the history class is employed differently (Schleppegrell, 2004) to communicate historical content since the language of history differs vastly from the LSS. Halliday (1993) referred to the ability of LoLT to serve the purposes of a particular discipline as the register of a discipline. As soon as the register is considered, then the question around language and teaching is no longer “Which language?” but rather “What are the language demands of the discipline?”

The researcher suggests a possible model for the language focus in classes of English first additional language learners (EFALs) as well as English home language learners (EHLs) represented in Figure 2.6 below. It is important that the learners should have a level of proficiency in LoLT because failing to address learners’ difficulty with the LoLT whilst teaching science, will make teachers guilty of Desai’s (2001, p. 329) assertion on the dominance of English as language of instruction,

> [y]et more than two decades later, many young children throughout South Africa, indeed, throughout Africa, are still being subjected to ‘incomprehensible education’.

However, the language of school science (LSS) places unique demands on the LoLT to the extent that EHLs likewise struggle to extract the intended meaning from science text.

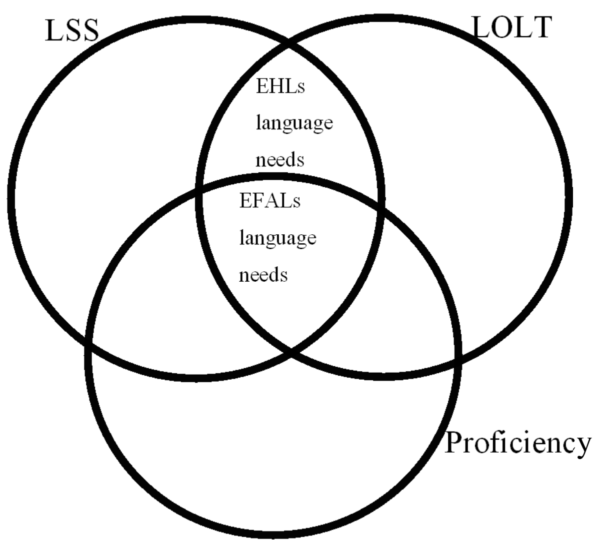

Figure 2.6: Language focus of English home and first additional language learners

The language needs of EHLs can therefore be represented (Figure 2.6) as being very similar to that of the EFALs with the exception of an emphasis on proficiency.

Louisa et al. (1989) provide an argument for the importance of LSS when they purported that the scientifically incorrectness that is contained in the natural language (LoLT) impedes the learning of science. The researcher therefore holds the opinion that replacing English words with isiXhosa words as in the following excerpt does not necessarily imply that conceptual understanding will result.

> … And now when you get frustrated, you re-explain, try to use other [English] words, in explaining the same thing. But then you notice you didn't get through. And now you can't again explain it in English, because you've tried twice. And then you tend to put *amagama isiXhosa* (Xhosa names) (Probyn, 2001, p. 26).

Lemke (1990, p. 160) makes an important distinction between learning science and learning a foreign language in that the latter is just a process of translating familiar thematic patterns from the vocabulary and grammar of one language to another whereas learning to talk science is learning to acquire different meaning from the "same resources of grammar".

Mere translation from English to home language or vice versa is therefore not what is required to ensure conceptual understanding. Probyn (2001) reports that most teachers in her study felt that the vernacular lacked subject terminology hence they had difficulty transferring conceptual understanding from home language to LoLT. She used the word "Xhosalising", coined by one of the teachers participating in the study, for the tendency to say, for example, "e-acid" rather than "an acid" in attempts to make the content more accessible.

Based on Probyn's (2001) report, teachers come across as intuitively aiming to achieve an articulation of different knowledges and ways of knowing and talking about that knowledge (Lemke, 1990) by using strategies like "code switching". Given the persistent poor results reported on in Chapter 1, actual outcomes of these attempts seem to succeed to

> relax the students, crack jokes, relieve the tension in the classroom; and negotiate students' cooperation and involvement (Probyn, 2001, p. 263).

These, unfortunately, are all outcomes that do not necessarily imply developing conceptual understanding of science concepts.

Chval et al. (2014) suggest that a means of addressing the challenge of proficiency is to develop curriculums and instructions that emphasise language rich environments, are cognitively stimulating tasks for learners and have multimodal communications (verbal, written, pictorial or animated). In addition, learners should be provided with ample opportunity to use the LoLT during discussions or whole class presentations in an attempt to scaffold learners from peripheral to full members of the science classroom community ((Lave & Wenger, 1991).

The science teachers who consider language learning and learning through language as essential elements of the learning process will explore, together with their learners, the manner(s) in which LSS employs LoLT to make it science content. This consideration will inevitably include the vocabulary and grammar teaching as set out in the conceptual framework.

2.10 Summary

A theoretical framework informed by Vygotsky's (1987) socio-cultural theory of learning, the concept of community of practice Lave and Wenger (1998) and Halliday's (1993) systemic functional linguistics theory facilitated a look at teachers' classroom language in context. A specific focus on field and the register variable mode allowed for an insight into the complexity of the language use in the science classroom. It also allowed the researcher to conclude to what extent language could be a barrier in the science classroom. Although this research only considered the contextual variable mode and field, it is important to mention that Halliday (1993) established that all three variables, field, mode and tenor are always present in any discourse.

The researcher also outlined a conceptual framework for this study. Based on this framework, language in the science classroom was considered as vocabulary as well as grammar, which necessitates a consideration of teachers' classroom talk not only from a word level but a language level as well. Literature that explored the challenges associated with language as grammar and vocabulary were reported on. Wellington and Osborne (2001) emphasise the role of the teacher in assisting learners to master the language of school science by calling for science teachers to see themselves as language teachers. The next chapter will report on the research design and methods employed during the study.

3 Chapter 3

Research Methodology

The six purposes of this chapter are to (1) state the research aims of this study; (2) describe the methodology of this study; (3) explain the sample selection; (4) state the ethical considerations followed in the study; (5) describe the procedure used in designing the instrument and collecting the data; and (6) describe the methods of analysis used.

3.1 Research aims

The aim of this research is to evaluate teachers' instructional language for awareness that

- familiar words that assume different meanings in the science classroom can hinder learners' understanding of science concepts
- vocabulary building is important in the science classroom
- the language of school science is a specialised language and teaching the features of this language is part of teaching science
- effective teaching of the LSS and LoLT simultaneously might be necessary for some learners.

3.2 Research questions

1 Given the polysemous nature of words, is there evidence of Physical Science teachers' awareness of the potential for confusion that the technical and non-technical words in a science context pose in the science classroom?

2 Do teachers consciously endeavour to teach towards establishing a common understanding amongst learners and the science community?

3 Do teachers provide a pedagogy that scaffolds language learning and learning through language?

The language used to construct knowledge, beliefs and worldviews in school science is distinct from the social language that learners use in their everyday ordinary life (Fang 2006). The extent to which meanings differ is concealed by the use of familiar English words to define and explain science concepts. The two categories of words that were of interest in answering research question 1 are *everyday words used in a science context* as well as *everyday words used as science concepts*.

Schleppegrell (2007)) identified the *semiotic nature* of language, *grammatical metaphor*, *dense noun sentences* and *normalisation* as some of the typical challenges that the LSS poses to learners. Semiotics can be defined as the study of how we make meaning using words images, symbols, actions and other modes of communication (Wellington & Osborne, 2001). The meaning construed by a certain text is a function of the grammatical choices made by the writer/speaker. Teaching Physical Science successfully requires that the teacher makes the language choices clear to learners. Research question 2 investigates the extent to which the Physical Science teachers enculturate learners in the meaning that science text can construe.

English First Additional Language learners (EFALs) as well as Home Language Learners (EHLs) experience difficulty with the LoLT when it is used to communicate science concepts. In their teaching of Physical Science, it should be evident that the teachers have put measures in place to assist learners with their particular language needs. Research question 3 probes the teachers' language use in order to reach this outcome.

3.3 Research design

This research design is a case study. Yin (2013, p. 16) describes a case study as an empirical inquiry that

- investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when
- the boundaries between phenomenon and context may not be clearly evident.

This study aimed to investigate teachers' language use in the science classroom. It therefore lent itself particularly well to a case study design in that answers to the research questions could only be satisfactorily obtained if the context was understood. The research was therefore conducted in the natural environment of the teacher's classroom. Yin (2013) identifies three other research designs, namely, experimental, historical or surveys. Experimental research designs were not deemed suitable for this particular research since they tend to separate that which is researched from its context. Although a historical research design is context dependent, events studied are usually non-contemporary. A case study, as a research design, also provides a more in-depth investigation of the context compared to the survey. The reason given by Yin (2013) being that case studies do not have the constraints of a limited number of items that can appear as with a survey.

Critics of case studies as a research design always mention the lack of an ability to generalise findings as one of the biggest drawbacks. The researcher shares the opinion of Flyvbjerg (2006) that all expert activity is a result of context-dependent knowledge and expertise. The ability to look in-depth at a phenomenon in context, as in a case study, provides an opportunity to derive authentic understandings of the participant teachers' awareness of the language of school science. Interview data and observations allowed the researcher to understand the language use of the participant teachers and provided an opportunity for triangulation that refers to the classic convergence or corroboration concerning the same phenomenon (Neuman, 2000).

This research made use of an interpretive qualitative research approach. Merriam (2002) describes an interpretive qualitative approach as one where the researcher is attempting to learn how individuals experience and interact with their social world. A research paradigm can be seen as the worldview that guides the research or investigation (Denzin & Lincoln, 1994). Qualitative research integrates inductive, subjective and contextually bound approaches (Morgan, 2007). It is therefore important to note the "set of interlocking philosophical assumptions and stances" (Greene & Caracelli, 1997, p. 6) that the researcher brings to the research. The purpose of the research paradigm is to help with the identification of the underlying basis used in constructing the research (Bogdan & Biklen, 1982). A research paradigm therefore serves as the lens or organising principle by which reality is interpreted (Morgan, 2007; Nieuwenhuis, 2007a).

3.4 Population and sampling

In this case study, two schools were selected for the purpose of comparing language practices of two teachers in different environments. Learners were grade 11 EFALs and EHLs respectively. Merriam (2002) describes the purpose of qualitative inquiry as seeking to understand the meaning of a phenomenon from the perspective of the participants. The actual detailed selection of a purposive sample is therefore of paramount importance since that is how most can be learned about the phenomenon under study.

3.4.1 Participating schools

Education in South African schools was administered separately and unequally during the apartheid era. African and White schools were at the extreme ends of privilege and neglect. This apartheid legacy is still prevalent in the present day schooling system.

> This racial categorization of schools provides an indication of difference in infrastructure, qualification of teachers, management, governance of schools, educational culture and resource base of schools, and socioeconomic status of learners (Dempster & Reddy, 2007, p. 907).

The listed differences are all factors identified as determining learner success rates in schooling. It is therefore not surprising that the results obtained in the National Senior Certificate (NSC), with exceptions, plays itself out along these racial lines. The researcher therefore selected schools from opposite ends of the spectrum to compare their language practices. The school in which Teacher A is teaching is situated in a "township" where the majority of learners are of African descent whereas the school where Teacher B is teaching is one of the top private schools in Gauteng.

3.4.2 Participating teachers

There was a migration of teachers of colour to formerly White schools post 1994 (Dowse, 2014). Black teachers teaching at historically White schools are also considered to be better teachers than their peers in the "township" schools.

Both teachers who participated in this study are male and of African descent. Teacher A is a Sepedi speaker whilst Teacher B speaks Tshivenda. The researcher approached them to establish if they were willing to participate in the study. Both expressed a willingness to form part of the study and provided the researcher with dates that would suit them to have a visitor in their classes.

The choice of participants was therefore important for two reasons. Firstly, to establish the level of awareness of the role that language plays when teaching science for the two teachers from these different settings. Secondly, it provided an opportunity to see if the setting required that the two teachers have to place different emphasis on language when teaching science given that they were both second language speakers. The two teachers who participated in this study fitted the abovementioned criteria. In addition, the researcher had amicable professional dealings with both teachers in the past. The teachers were therefore more likely to reflect from the onset their true style of teaching making the findings more trustworthy.

3.4.3 Teaching experience

The aim of this research was to establish whether teachers reflected an awareness of the language difficulty experienced by learners. The more experienced teacher is less likely to grapple with content mastery, thus providing an opportunity to analyse language use as a separate variable. Both teachers had between eighteen and twenty years' experience in teaching Physical Science. They have developed professional competence and are regarded as master teachers in their respective circles. The researcher was therefore confident that, given their credentials, if language is part of these teachers' teaching focus, then it will be evident in their teaching as one of the tools that they employ when teaching science.

3.4.4 Teacher qualification

The 2010 TIMSS study reported that only 60% of the Mathematics learners in South Africa and 53% of the Physical Science learners were taught by teachers who had completed a degree. Internationally, 87% of Mathematics learners and 90% of Physical Science learners are taught by teachers with degrees. The large discrepancy between the performance of South African learners and their international counterparts compels one to look at the qualifications of the teachers participating in the study. Both teachers have tertiary qualifications and are therefore well suited to teach Physical Science. This choice again allowed the researcher to place emphasis on the contributions that their language use makes to the teaching of science. Table 3.1 serves to summarise the population and sampling for this research.

Table 3.1 *Summary of selection particulars*

Criteria	Teacher B	Teacher A
3.3.1 Participating school	Top private in suburbs	Government school in township
3.3.2 Participating teacher	African	African
3.3.3 Learner grade	Grade 11	Grade 11
3.3.4 Learner language	EHLs	EFALs
3.3.5 Teaching experience	18-20 years	18-20 years
3.3.6 Teacher qualification	Tertiary qualification	Tertiary qualification

The learners in Teacher B's classroom were of White, Asian and African descent, but they were all registered as EHLs. It is therefore evident from Table 3.1 that, in their respective settings, it is only the language of learning and teaching (LoLT) that distinguished the teachers.

3.4.5 Learner Grade

The National Senior Certificate (NSC) is an important benchmark to measure the state of MST in South Africa. Considering teacher practices in the FET band may cast light on areas where teachers' use of the language of school science (LSS) contributes to the current poor results in Physical Science. By their FET year, unlike in the lower grades of schooling, it is expected that complex forms of LSS will be present within teachers' language use. Grammatical metaphors, one of the characteristics of LSS that contributes to its difficulty, according to Halliday (1993), is only acquired by learners later on in their development of LSS. An evaluation of teacher awareness of LSS is therefore much more meaningful in the FET band.

The sample was obtained from grade 11 Physical Science learners attending the two selected schools. School A had 25 grade 11 Physical Science learners of which 11 were girls and 14 were boys. School B is a boys school hence the Physical Science classroom that was visited for the observation had 20 grade 11 boys attending. The areas covered in the grade 11 Physical Science syllabus is rife with content that is renowned for being difficult to understand. Geometric Optics and Mechanics, which were the topics that were taught at the respective schools during the observation period, are amongst the most researched areas for the difficulties that they pose for learners.

3.4.6 Learner language

In Chapter 2, it became evident from the literature reviewed that LSS has proven to be difficult for both English First Additional Language learners (EFALs) and home language learners (EHLs). To answer research questions 2 and 3 therefore warranted an investigation of teacher language use in classrooms where these groups of learners were taught. Since both teachers in this study are English second language speakers, the observation of EHLs and EFALs allowed for a comparison of teacher language use as influenced by learners' need for support in LoLT. The researcher was interested in establishing if there were comparable differences in language use of the teachers in these two classrooms.

3.5 Ethics

Webster's New World Dictionary defines ethical behaviour as "conforming to the standards of conduct of a given profession or group". The Committee on Scientific and Professional Ethics of the American Psychological Association issued the following statement regarding ethical principles for the conduct of research with human participants:

> The decision to undertake research rests upon a considered judgement by the individual educator about how best to contribute to science and human welfare. Having made the decision to conduct research, the educator considers alternative directions in which research energies and resources might be invested. On the basis of this consideration, the educator carries out the investigation with respect and concern for the dignity and welfare of the people who participate and with cognisance of federal and state regulations and professional standards governing the conduct of research with human participants (Fraenkel, Wallen, & Hyun, 1993, p. 32).

The above statement highlights important considerations of obeying professional standards governing conduct of research, respect for persons, welfare of persons and confidentiality. The researcher addressed these considerations as follows:

3.5.1 Ethical clearance

In order to conduct this research, permission had to be obtained from the Ethics Committee in Education of the Faculty of Humanities, University of the Witwatersrand. After submission of a research proposal, permission was granted. See Appendix 1.

3.5.2 Respect for persons

Each participant was informed of the nature of the study and was subsequently invited to take part in the study. Each letter had a consent form attached. Since the learners were minors, consent had to be obtained from the parents as well. The research was only conducted after completed consent forms were returned. Participants were aware of the fact that they could withdraw from the study at any point (Leedy & Ormrod, 2001).

3.5.3 Protecting participants from harm

Almost all educational research involves activities that are regarded as containing very low potential to harm participants. This particular research can also be considered as low risk in that the researcher first visited classrooms without taking any video recordings. Learners became used to the presence of the researcher and regarded her as someone that the school sanctioned as being safe. The videotapes are locked in a cupboard and only the researcher has access to it. This limits the possibility of participants being identified.

3.5.4 Ensuring confidentiality of research data

Allmark et al. (2009) identify the biggest threat to confidentiality to be in the writing up of reports. They state that, although individuals may not be known to the public, quotes may identify them to the other participants involved in the study. In light of this consideration, the researcher consulted with participants regularly to ensure that they were aware of the intentions of the researcher. Consent forms clearly stated that the videotapes, audiotapes and transcripts will be saved on an external hard drive which will be locked away in a secure place when not used by the researcher. Such data will be destroyed 3-5 years after completion of the project. It was also understood by the participant that any further use of data and other material will require a new ethics clearance application for consideration by the ethics committee. Participants were also informed that they may request that data collected not to be used.

3.5.5 Deception of participants

In no way did this research use methods that involved deception. The researcher was open with the teachers about the reason why they would be observed. A raised awareness of the importance of word meaning can only benefit teaching in general hence, it was not considered necessary to keep the reason for observing the lesson from the teacher.

3.6 Data collection method

This research was conducted by observing two teachers' teaching in their natural environments with a specific emphasis on the teachers' language use. Below is a description of the methods that were employed to collect the data.

3.6.1 Observation of teacher's classroom practice

It necessitated observation of the actual lessons presented by the teacher in order to answer the research questions 1 to 3. Observation is a practice that lends itself particularly well to qualitative research. The research is conducted within a particular context, at the site in line with the methodology akin to qualitative analysis. The fundamentals of qualitative research are that meaning is socially constructed by individuals in interacting with their world (Merriam, 2002) because that which is researched can only be understood in its particular context (Creswell, 2007; Nieuwenhuis, 2007a). The classroom observations therefore provided an opportunity to see the teachers' actual practices as they went about their daily routine. The objective with participant observation is to collect data in a naturalistic environment which engages natural behaviour research (Bogdan & Biklen, 1982). It therefore was important that my presence as researcher only minimally affected the natural events in the classroom. Nieuwenhuis (2007b) identified four types of observers as outlined in Table 3.2:

Table 3.2 *Type of observer (Nieuwenhuis, 2007b)*

TYPE OF OBSERVER	**CHARACTERISTICS**
Complete observer	Non-participant, looking from a distance, least obtrusive
Observer	Involved as observer mainly, does not influence dynamics of setting
Participant	Action research, may intervene and change in dynamics
Complete participant	Those observed are unaware that they are subjects of observation, ethical concerns

This researcher adopted the role of Observer as categorised by Nieuwenhuis (2007b) as it was important to be present in the classroom in order to make certain conclusions. However, the researcher sat at the back of the classroom to ensure the least influence on the dynamics of the setting.

Observations of two teachers' teaching in their classrooms were made with the use of video camera recordings of their lessons. The decision to make use of video recordings was motivated by the fact that observation, by its very nature, is highly subjective and selective. We tend to observe a specific event or object within the whole, therefore cutting us off from the whole (Nieuwenhuis, 2007b). The videotapes allowed for an opportunity to relive the episode and to pick up on the nuances that might have been missed during the initial observation. The video recordings were transcribed and used for data analysis.

The recording of data during observation was enriched by creating anecdotal records. Nieuwenhuis (2007b) describes this as short descriptions of basic actions observed capturing key phrases or words. This data should not contain any self-reflective notes and reflection should happen as soon as possible after observation though.

3.6.1.1 Outline of lessons observed

The researcher is of the opinion that the number of opportunities to observe the teacher was important for this gave an indication of how the language was used to convey science meaning. For this reason, wherever possible, observation of topics from introduction to conclusion was done. It was possible to observe all Teacher A's lessons on the topic of Geometric Optics. Teacher B had already started Mechanics by the time the opportunity availed itself to observe his lessons. Although it was not possible to observe the topic from introduction, it was possible to observe complete sections within the topic. Below is an outline of the lessons, topics and duration of the observation. Table 3.3 below represents an outline of the observations that were made in Teacher B's classroom. In total, six lessons, each with a duration of 50 minutes, were observed in Teacher B's classroom.

Table 3.3 *Outline of lessons observed for Teacher B*

TEACHER	CONTENT	TOPICS	Number of observations
B	Mechanics	Elastic and inelastic Collisions Impulse Momentum Theory Applications of Momentum	6 x 50 min

Table 3.4 below outlines the observations made in Teacher A's classroom. Teacher A was observed for seven lessons that each lasted 40 minutes.

Table 3.4 *Outline of lessons observed for Teacher A*

TEACHER	CONTENT	TOPICS	Number of observations
A	Geometrical optics	Terminology of Geometric optics Laws of reflection Refraction Snell's Law (3) Critical Angle Total internal refraction	7 x 40 min

3.6.2 The teacher interviews

The researcher had informal conversations with both teachers throughout the observation period during which field notes were taken. In addition, an hour long formal interview with each teacher respectively was conducted after all observations were completed. The interviews were used as a means of triangulation to corroborate conclusions that the researcher formed from the observations. Neuman (2000, p. 274) describes the interview as "a short-term, secondary interaction between two strangers with the explicit purpose of one person obtaining specific information from the other". The purpose of the interview was primarily to answer research questions 1 and 2.

Interviews can be structured, semi-structured, informal or retrospective. The interviews conducted in this research were semi-structured. The decision to use this format was taken because the fairly formal nature of this type of questioning ensured that specific answers were elicited from respondents. The information obtained was also easily compared and contrasted. Questions were worded in an open-ended format. The advantage of this type of questioning is that it reduces the interviewer's influence (Fraenkel et al., 1993) in that it allows participants to add information that the interviewer might not have asked for and therefore afforded better insight into the situation. Since interviews were conducted after the observation of all the lessons it allowed the researcher to get a complete overview of the teacher's manner of language use. In addition, in so doing, the possibility that the teacher might change his approach to language based on the interview discussion was also eliminated.

3.7 Instrumentation

3.7.1 Observation schedule

When observing a teacher's classroom interactions, special notice was taken of the manner of language use by the science teacher. Barnes et al. (1969; as cited in Wellington and Osborne, 2001, p. 86) used the following categories to analyse teachers' language used in the science classroom: Specialist language presented, Specialist language not presented and Language of secondary education. The description of each of these categories is discussed in Table 9.1 (see Appendix 2). Specialist language refers to the vocabulary used that is unique to the topic discussed. Language of secondary education has the same meaning as language of school science. The use of dense noun structures, grammatical metaphors and nominalisations were noted.

3.7.2 Interview schedule

The interview schedule had broad concepts for which the researcher sought answers. Four broad concepts that covered the research questions were focused on during the interview, namely, *awareness of polysemous nature of words*, the needs of *second language learners* in the science classroom, *science meaning vs everyday meaning* and *language of school science*. Table 10.1 (see Appendix 3) shows examples of sample questions that were asked for each of the concepts.

3.8 Method of analysis

Data obtained from the classroom observations and teacher interviews were transcribed and used for analysis. The analysis focused on (1) teachers' vocabulary building attempts; (2) how the teacher developed learners' language of school science (LSS); (3) the simultaneous teaching of language of learning and teaching (LoLT) and Physical Science concepts using LSS. Adopting this approach effectively divided this analysis into three aspects of language use in the science classroom, namely, language as tool, as medium and as words (Figure 3.1 below). Language as a tool focused on how the science teachers used the language of school science (LSS) to convey science meaning. Language as a medium gave insight into the teachers' awareness of their learners' competencies with the language of learning and teaching (LoLT) and the support they provided during teaching. Language as words focused on teachers' vocabulary building in the classroom.

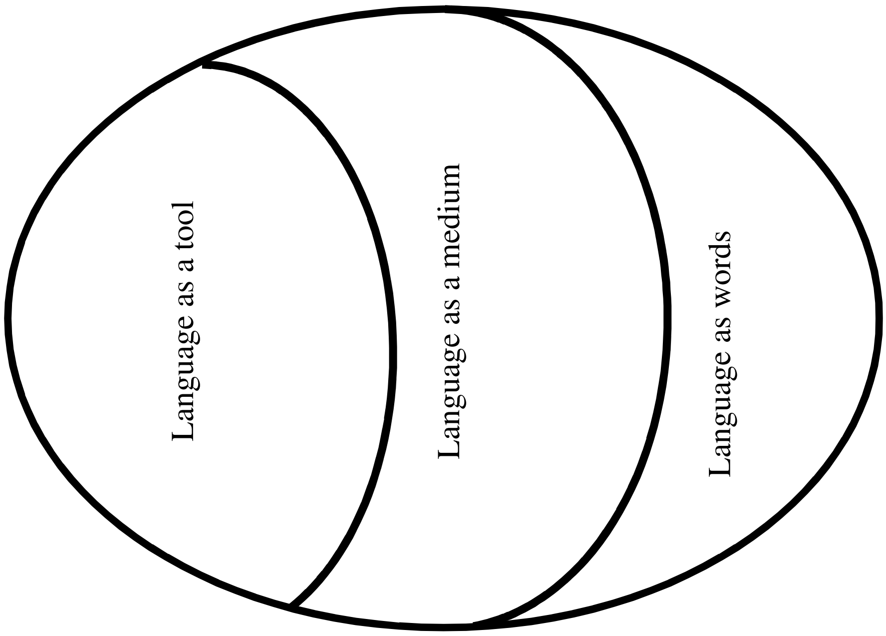

Figure 3.1 Analysis of language use in the science classroom

Figure 3.2 below gives an outline of the presentation of the analysis discussed above. The register variable field is interrogated under Teachers' vocabulary building in the science classroom. Mode allows a method of analysing teachers' language learning opportunities provided to learners. The mode register variable is used to analyse the nature of the language used by the teacher and whether it contains the unique features that make it so challenging for learners. In addition, it also looks at the teacher's awareness of the difficulties that the language features pose to learners. The language practices in the science classroom focus on the language needs of the learners. The language needs for EHLs differs from that of EFALs as indicated in the earlier chapter yet both groups of learners must, in the end, learn the LSS.

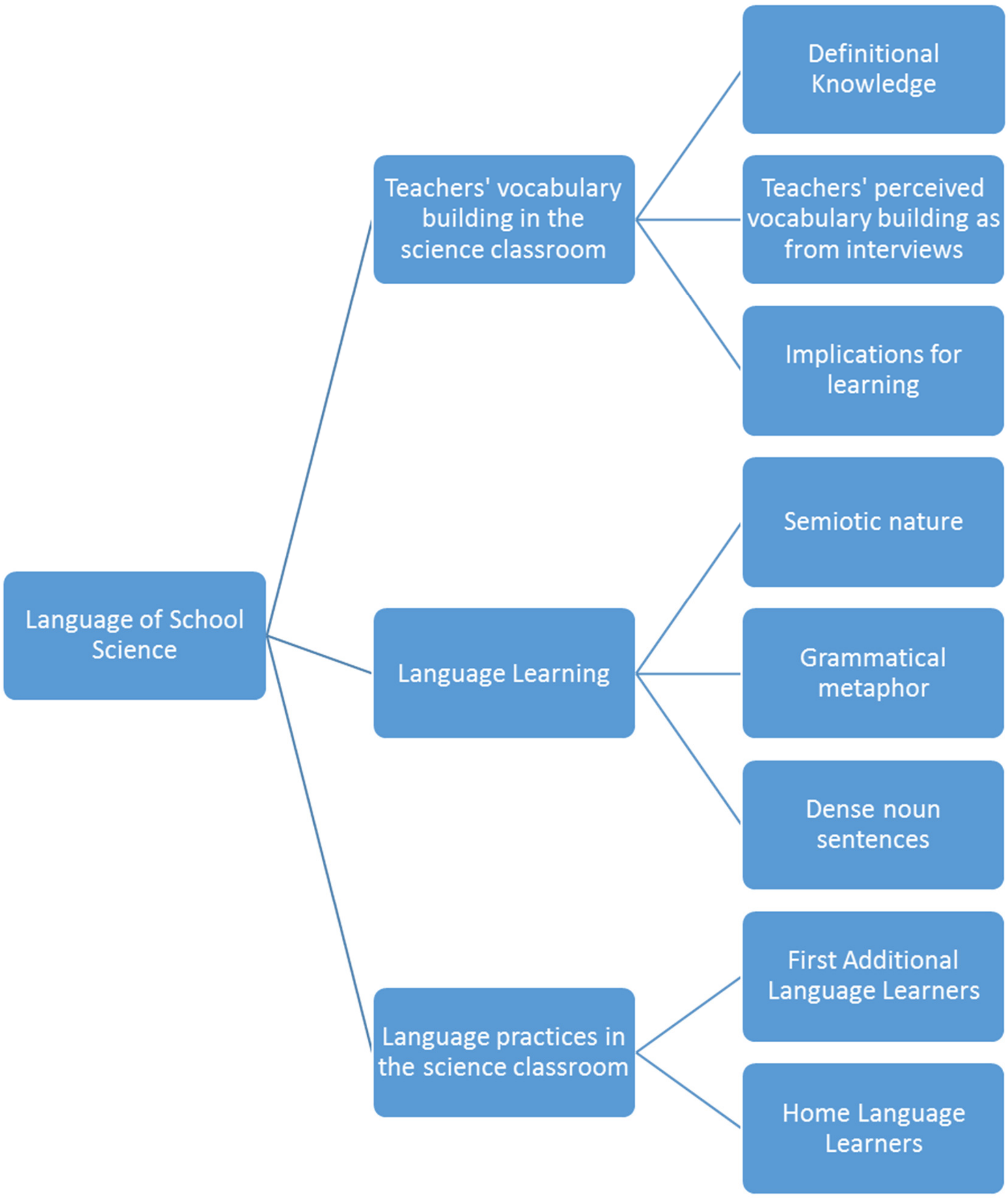

Figure 3.2 Outline of presentation of analysis

3.8.1 Vocabulary building focusing on polysemy

Transcriptions obtained from classroom observations were utilised to perform this part of the analysis. Science words can be divided into two components, a technical and non-technical component (Oyoo, 2012). The non-technical component refers to *non-technical words in the science context*, *meta-representational terms* and *logical connectives*. Figure 3.3 below extended the schematic representation (Figure 2.3) of how words used by the teacher are categorised to indicate the focus of analysis in this research report. The researcher concentrated on the familiar English words that are defined as *technical words used as science concepts* and the *non-technical words used in a science context.* The difference between these categories was discussed in detail in Chapter 2. Under each category, words were subsequently sub-divided into *explained* or *not explained* words. The researcher made use of content analysis (Krippendorff, 2012) to compile a list of the words used by the teacher. A selection of words was made based on their relevance to the topics discussed. The researcher therefore, by no means, attempted to account for all the words that the teachers used during their science lessons. The principal interest was to determine the number of topic related words that may remain unexplained during a science lesson. As the analysis progressed, the researcher realised that it was necessary to interrogate the nature of the explanation as that determined the quality of the teacher talk. Explanations were categorised as *Explicit* or *Implicit interpretation*.

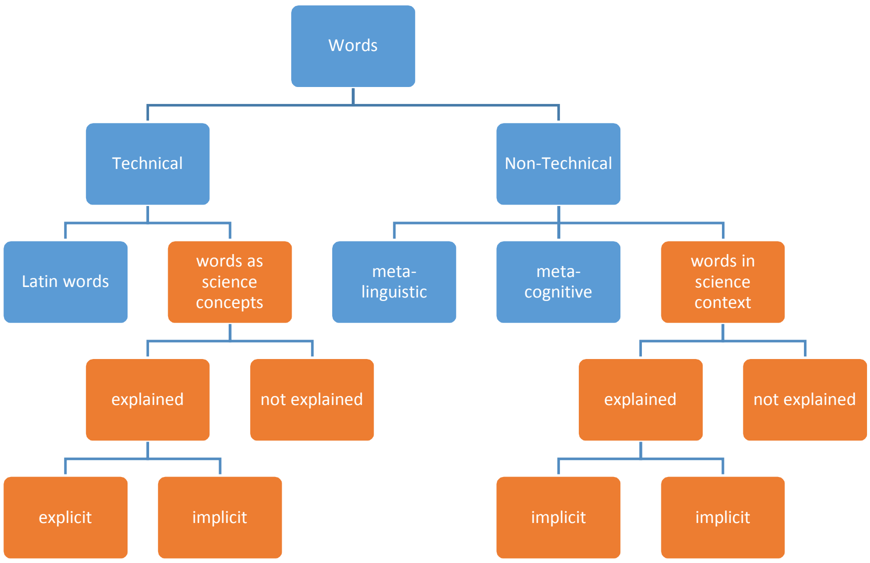

Figure 3.3 Analysis of language as words

This categorisation is influenced by Sutton's (1992) view of language as an interpretive system. Sutton (1992) is of the opinion that a speaker who uses language as an interpretive system will display a general awareness of what meaning they wish to convey and will ensure that they make word choices accordingly because "a speaker or writer is aware that there is room for doubt about how an idea shall be expressed, and therefore makes a careful choice of words in order to capture the idea as closely as possible" (p. 49). When the teacher stated a definition or defined a concept, it was categorised under *implicit interpretation.* Instances where the teacher used examples or drawings to elaborate on explanations of concepts, were categorised as *explicit interpretations.* Occurrences, where teachers used words without explaining their meanings, were categorised as *no explanation.* A detailed report on this analysis and the results obtained is provided in Chapter 4.

3.8.2 Analysis of Language Learning opportunities in the teachers' use of Language of School Science (LSS)

Analysis of the language use of the teachers was done using the methods of systemic functional linguistics (see Figure 2.1), in particular, analysing the register variable mode. Mode refers to the role that language plays in the interaction. Specific focus was on lexical packaging of the language through *grammatical metaphor*, *dense noun sentences* and *nominalisation*. Systemic functional linguist refer to the above features of LSS as "highly sensitive to mode variation" (Eggins, 2004, p. 94).

The researcher therefore first looked for evidence that teachers' classroom talk contained the difficulties referred to above. Secondly, the analysis demonstrated how failure to make learners aware of the difficulties inherent in the language of school science adversely affected learner understanding in the two classrooms.

The researcher was interested in how teachers used linguistic resources to convey science meaning. In addition, the researcher explored whether the manner in which language is structured can lead to learners' understanding that is not congruent with that of the science community. Awareness from the teachers' side of the possible disconnect that can exist between LSS and the meanings that learners derive from it will also be considered. Following is an account of the methods employed to analyse the teachers' language for the linguistic features.

3.8.2.1 Nominalisation

The researcher read the transcripts carefully for the nominalisations in the text from the respective teachers. This was analysed, firstly, for the prevalence of nominalisation in teachers' speech bearing in mind that Halliday (1993) indicated that grammatical metaphor, of which nominalisation is an example, is a difficult feature of language and it is acquired later in speech development. In addition, the analysis focused on the level of unpacking that teachers embarked on when using nominalisation. The example of analysis that follows (Table 3.5) is from Young and Nguyen (2002, p. 11). A similar approached was adopted in this research.

Table 3.5 Analysis of grammatical metaphor

The *law of reflection* • the law of how things reflect light [Explicit unpacking of nominalisation – *law of reflection*] • the law of how light bounces back when it hits things [Explicit unpacking of technical term *reflect*]

In Table 3.5 above, the noun phrase "the law of reflection" is a grammatical metaphor for the everyday speak "the law of how things reflect light". Should the teacher use a sentence that brings the nominalisation back to its verb form like the example of *reflection* and *reflect* in Table 3.5, then the researcher will consider this as *explicit unpacking of nominalisation*. The technical term "reflect" also needs to be unpacked in order to yield the commonsense meaning, "the law of how light bounces back when it hits things". The researcher will regard this as *unpacking of the technical term.*

By making use of the approach demonstrated above, it is possible to measure the effectiveness of the strategies employed by the teachers to successfully address the difficulty that grammatical metaphor poses to understanding LSS.

3.8.2.2 Dense noun sentences

Nominalisation leads to dense noun sentences. The lexical density refers to the ratio of nouns to the number of clauses in a particular text. Sentences with a high lexical density imply that learners need to grapple with a large amount of information to uncover the intended meaning. Everyday language use does not contain as many content words hence learners need to be exposed to this manner of language use. However, a caution to refrain from making the language unnecessarily difficult should accompany a request to enculturate learners in the language of school science. Two separate episodes were extracted from transcripts of Teacher A and B's teaching observations respectively. The episodes were selected for their comparative length and complexity of the topic discussed. These were analysed for the lexical density in the speech of each teacher. The higher lexical density refers to language use that would generally be more difficult to understand.

3.8.3 Semiotic nature of the language of school science

The relationship between an equation and its graphical representation was explored during an episode in Teacher A's classroom. The researcher demonstrated how an inability to make the necessary links between the words, symbols and the graphical representation led to the learners' difficulty in comprehending the subject matter. Equations and the meaning that the equal sign communicates were explored as learners displayed difficulty in understanding this meaning during an episode in Teacher B's classroom.

Transcripts were read to identify episodes where the teacher made use of oral, written, symbolic and graphical representations collectively to construct the meaning of a concept. Qualitative analysis of these texts focused on

- the semiotic resources teachers used when they explained concepts
- how the representation and communication of semiotic resources correlate or differ
- how teachers organised the resources
- representational modes used by the teachers to make meaning.

3.8.4 English First additional language learning

This section of the analysis considered Teacher A's attempts at providing language support to his learners with a specific focus on code switching. This was done with the aim of answering research question 3.

A language practice that was evident in Teacher A's classroom and subsequently further interrogated was that of code switching. To form conclusions on the nature and effectiveness of this language practice, the researcher watched the videos for Teacher A's classroom talk and read the transcripts. The watching of the video was important this time to make sure that non-verbal attempts to assist with meaning making were also noted. Each word or sentence uttered in the vernacular was listed and translated into English. A further step of this analysis included the categorisation of utterances in terms of the functions that they fulfilled. The following categories were adopted from Probyn (2015, p. 224), namely, language use for:

(1) constructing and transmitting knowledge

(2) classroom management

(3) interpersonal relations and to humanise the classroom climate.

3.8.5 English Home language learning

In Chapter 2 the researcher suggested a model (Figure 2.6) that represents the language needs of EHLs. In line with Bailey, Butler, LaFramenta, and Ong (2004) who consider academic language as a second language for many learners, the impact that language have on learning should therefore always be a consideration when teaching science even to EHLs. As Wong-Fillmore and Snow (2000) write, "Teachers need to understand how to design the classroom language environment so as to optimize language and literacy learning and to avoid linguistic obstacles to content area learning" (p. 8).

Moving from the premise that learning science is learning to talk science (Lemke 1990), an analysis of Teacher B's language practices focused on the opportunities that he provided to his learners to do science by mastering the language of science (Ross & Frey, 2009). Teacher B's constructivist approach to teaching provided ample opportunity for learners to engage in language practices through inquiry. These classroom episodes were scrutinised for:

- Opportunities provided to learners to talk science
- Effective modeling of the use of science language
- Discussions about language

This analysis of Teacher B's awareness of the language needs of EHLs leads to a focus on how he was teaching the enacted curriculum. His teaching practices were compared to how Geelan (2013) analysed practices of 21 excellent teachers. This will be discussed further in Chapter 4.

3.9 Summary

In this chapter, the methodology and research methods were discussed. The researcher made use of a case study as this form of research design lent itself well to the intentions of an in-depth investigation of a phenomenon. Data collection methods involved video recordings of classroom observations and follow-up interviews with the teachers involved. A report on how ethics was observed during the study was also provided. Methods for analysing language as words, a medium and as a tool to convey science was considered as vocabulary building, language learning and language needs of EHLs and EFALs. The data analysis and findings of this study are presented in Chapter 4.

4 Chapter 4

Data Analysis and Findings

4.1 Introduction

The language of school science (LSS) refers to both its specialised vocabulary and the linguistic devices employed to convey scientific meaning. Schleppegrell (2004) refers to this as the register of school science. Familiarity with the register contributes to greater congruency between learner understanding of science concepts and that of the science community.

In order to investigate teachers' awareness of the polysemous nature of science words and the implications it has for vocabulary building during the teaching process, an analysis of teachers' word use was made.

In this chapter, linguistic resources employed in school science were analysed from a systemic functional linguistics (SFL) perspective to determine teachers' awareness of how their language use can contribute to the difficulties in learning science.

A final aspect of the analysis in this research addressed the issue of English First Additional Language Learners (EFALs) and Home Language Learners (EHLs) and their unique struggles in the science classroom.

4.2 On a word level

Research question 1 concerned itself with the vocabulary encountered when learning Physical Science topics. Polysemy, as defined in Chapter 2, refers to the many related and sometimes unrelated meanings that can be assigned to one specific word. The research question was asked because the teacher as speaker and the learner as listener need to have a shared meaning in order to, firstly, ensure that both know that the discussion is about science and, secondly, both teacher and learner share a common understanding of the science meaning of that which is discussed. The first aim is fairly easily achieved by the context of a science classroom setting. Both teachers observed in this research pointed out that, although words may assume many meanings when used in everyday conversations, in science, those words are associated with an equation or a diagram. Learners will readily associate the word with science when confronted with that word in the science classroom. Below are excerpts from interview responses that the researcher conducted with the two teachers concerning polysemy.

R: Impulse will have a meaning like "on impulse I do that", or I do that but there is also a scientific meaning for impulse. How do you find those two situations? Do you find that they actually in any way overlap in a class situation or not?

Teacher A: Normally, to give an emphasis for words especially meaning in science most of them luckily I would say between 50 to 60% they come along that is with some equation. … So that is normally how you keep a link of saying that it is not an English word that you could use outside without context but it is a word that you can use within the context of science with a definite meaning.

The following was Teacher B's response to why he was confident that learners would know that familiar words refer to science concepts when they are used in the science classroom.

R: I was thinking to what extent is that maybe linked to impulse as we understand impulse in our everyday? If it is an impulsive reaction or impulsive move you tend to do things to something as appose to .... you never see something reacting on ...

Teacher B: Oh, I see what you mean. Hence, if you are to use the diagram and you say ball to the wall, wall to the ball putting arrows then … with the help of a diagram I think that one can be eliminated.

The above demonstrated the first aim, namely, that the teachers appeared to be fairly sure that learners throughout the discussion would be aware that there is a science word, *impulse*, in the physics register and might even know how to use it in calculations. The second aim, namely, to ensure congruency of meaning assigned to science words, might not have been established yet. Overt reliance on context only works when there is a high level of shared understanding, in other words, teacher and learners must assign the same meaning to the word *impulse*. It therefore becomes clear, given the nature and purpose of teaching that it would be risky to assume that learners are already sharing the same cultural identity that the teacher is sharing with the science community. For this reason, teachers must also incorporate vocabulary building in their teaching. What follows is a report on the teachers' awareness of the importance of vocabulary building with a specific focus on the polysemous nature of words. This was achieved by considering vocabulary building attempts in the science classroom. Afterwards, teachers' "best practices", regarding vocabulary building as per their interview responses, were investigated. The interview and observation findings were used as a means to triangulate conclusions.

4.2.1 Teachers' vocabulary building in the science classroom − focus on polysemy

A motivating reason for building vocabulary in the science classroom is that words are polysemous. Science makes use of the same words that are used in everyday conversations but when used in the science classroom, they assume new and precise meanings. Literature identified *non-technical words in a science context* and *technical words as science concepts* as particularly problematic for science learners (Strömdahl, 2012). Part of the reason is that these familiar words take on unfamiliar meanings when used in science context. Teacher use of these two categories of words is investigated below.

4.2.1.1 Teacher's use of everyday words in science context

Table 4.1 below represents an analysis of Teacher A's use of *non-technical words in a science context*. The words were categorised as *explicitly*, *implicitly* and *not interpreted*. The text that served as motivation for the categorisation is provided in a column next to each word. Words that were not explained do not have any text accompanying them.

Teacher A

Table 4.1 below reflects that the majority of the everyday words used in science context were not explained by Teacher A. Following is a discussion of the implications for learner understanding in the science classroom by looking at a few words from the last column in Table 4.1.

The words *regular way* was used to describe to learners the manner of reflection from a smooth surface like a mirror. It is unlikely that learners when using their everyday understanding of the word *regular*, will come to the conclusion that the image, formed as a result of reflection from a smooth surface, would not be distorted. Explicit attention to the change in meaning when the word *regular* was used in a science context is therefore necessary to ensure that the teacher and the learner share a common understanding.

Table 4.1 *Words in science context used by Teacher A*

Investigating teachers' use of *non-technical words in science context*				
Explicit Interpreting		**Implicit Interpreting**		**No Interpreting**
Word	**Text**	**Word**	**Text**	**Words**
properties	Then the properties or the things that could happen, that is, with light.	reflection	Reflection is when a shiny and smooth surface like, for example, like a mirror will reflect	substance medias imaginary line
retardation	Yes, it becomes slightly slower. It's like it experience retardation, it's being retarded. It becomes slower and slower.			regular way reserve bending define
dependent	The independent one is the one that is made by the specific choice. Those ones your incident they have made that it is a specific choice. Saying that if you push your light you say that I want a specific angle depends … on you to control it.	normal	The normal, so the normal by definition is an imaginary line at 90 degrees to the surface of the mirror.	relationship notation probability terms substitute differentiate
independent	But the light the refracted ray that comes out there is independent if … it becomes either as I said it is small if it's 20 it is 13 if it's 30 it's 19.			emerge constant medium

Words like *constant*, *medium* and *terms* have distinctly different meanings in the physics and mathematics classrooms and, when not interpreted by the teachers, learners are left to find their own meanings. Later in this chapter, the researcher discusses an episode where the different meaning of words in the two disciplines caused the learner to find it difficult to understand the physics concept. Learners therefore had to deal with the varying meanings of words over disciplines within the school context as well as the meanings these words ascribe to in their everyday encounters.

Finally, the episode below is an excerpt in the science classroom where Teacher A, by means of a sketch, explained how refraction happens between two mediums. In this illustration, the focus on the everyday meaning of *bend/bending*, i.e., to shape or force something straight into a curve or an angle, has the potential to conceal the science meaning and, in the process, leave the learner unable to make important connections between concepts.

> *T: … That will be your incident angle, you would have that incident ray bending and it will bend that it is towards where?*
>
> *L: Normal*
>
> *T: It will bend towards so it means it won't be that straight ne? It will bend that it is towards the normal. …. So, with this one, what it slightly differs is what? It's the angle. That angle it will be what? The angle of what?*
>
> *L: Refraction*
>
> *T: … So it means in that particular medium, you'd have two angles that are equal, why it is because the medium is the same ne?*

From the described episode, the message that is conveyed is that of a literal meaning of the bending of a light ray unrelated to the type of medium and the speed of the light rays in that particular medium. The only related issues are the angle size as is the case in everyday understanding of any bending.

The learner may, at best, acknowledge the importance of two distinct mediums but will not be in a position to connect refraction with the optical density of the mediums. The emphasis on the fact that the ray is no longer straight but forms an angle, leaves the learner with an everyday understanding of the word *bending/bend* namely *flex, angle, bow, stoop* or *hunch*. The learner may never form conceptual links, as represented in Table 4.2 below. The learner might not link the bending of the light rays with its change of direction in a medium with a different optical density and the different speeds responsible for the turning towards or away from the normal.

Table 4.2 *Word links in geometric optics*

refraction →	bend →	change direction →	medium →	
optical density →	slower/faster speed →	toward/away from normal		

Teacher B

Table 4.3 below shows an analysis of Teacher B's use of *non-technical words in a science context*. As was the case with Teacher A, Teacher B also did not focus on vocabulary building during the teaching of science topics. Most of the words relevant to understanding the topic came under the "No interpreting" column. Teacher B made effective use of learners' English understanding of the words *elastic* and *inelastic* hence he explained inelastic collisions and simply had to ask learners what the opposite of inelastic was, to come to an explanation of elastic collision. Teacher B also ensured that learners shared the same meaning for the word *stationary* by unpacking it into "it is not moving". He also then extended the meaning of stationary to when the velocity of an object is zero. There were, unfortunately, also cases of implicit interpretation that complicated learners' understanding of concepts. The word *direction* was mostly explained as being a property of a vector but not of a scalar. However, learners also needed to deal with directions as being east or west, towards or away to mention but a few examples. This created confusion amongst learners as they were unsure how to bring each instance back to positive or negative given the inconsistency of which direction can be considered negative or positive. Following is an excerpt where Teacher B dealt with a learner who was answering a question in which he needed to provide direction:

> *T: You head the ball. Then, this is away from the head. So now, think about it, which direction are you making positive?*
>
> *L: The positive direction*
>
> *LL: Laughter*
>
> *T: When the ball is coming or going*
>
> *LL: Coming / Going*
>
> *T: Coming? 4m/s will be positive? Ok, now, all right*

Teacher B had to make a decision on behalf of the class, without explicitly giving reasons for his choice. The learners who selected *going* as the positive direction might assume they were wrong in doing so.

Table 4.3 Words in science context used by Teacher B

Investigating teachers' use of *non-technical words in science context*				
Explicit Interpreting		**Implicit Interpreting**		**No Interpreting**
Word	**Text**	**Word**	**Text**	**Words**
Contact time	So that time when the ball was in contact with the wall this is the time, ok. So it is the duration, the time when the two objects are in contact with each other.	Scalar	T: Energy is a scalar, it is not a vector.	Resultant Net average
Inelastic collision	In our situation here, the two kinetic energies are not equal. So this type of collision we are going to call it inelastic collision. Inelastic collision. So what is inelastic collision? This is when the two objects collided, the energy before is not equal to the energy after.	Vector	T: … whereas momentum is a vector quantity you'll then have to write the direction as well.	initial final energy momentum
Elastic collision	What is the opposite of that? L: Elastic T: Elastic collision. In elastic collision Ek before will be equal to Ek after the collision.	direction	It is a good practice … to show that direction when you are asked to calculate momentum but if you are asked to calculate energy, it's not necessary cause energy is a scalar.	conservation convert constant
conserved	With the energy we usually use it, remember energy at most instances is not conserved, there are some other forms of energy like sound like heat etc. so that energy can be transferred to that. Ok, yes?			same impulse friction initial
stationary	T: ... not moving, v is zero			isolated Physical quantity

Given the number of unexplained words used by Teacher B, as indicated in Table 4.3 above, it becomes clear that he did not spend enough time ensuring that learners share his intended meaning of words. The excerpt below from one of the teaching episodes demonstrates the inadequate emphasis on vocabulary building, as part of a teaching strategy for Teacher B:

T: … Maybe before the example shall we remind ourselves what does fnet mean? What is fnet?

L: It's a force, Sir, a resulting force!

T: A resultant force, ok resultant force. And what is that delta t?

The researcher is of the opinion that Teacher B should have placed much more emphasis on the difference between *resulting* and *resultant* as used in the science classroom. The researcher believes that the intervention provided by Teacher B was appropriate for correcting pronunciation. What was needed, in this particular instance, was developing the learner's vocabulary to promote conceptual understanding. The likelihood that the learner's conceptual understanding of a *resultant force* is guided by his understanding of the word *resulting* was high.

Every time Teacher B asked learners to account for the difference in kinetic energy during an inelastic collision, learners named friction as one of the energy forms that kinetic energy was converted into. This is a direct result of an everyday understanding of energy as a mechanism that can explain how and why an event happens rather than a number that has to tally at the end of an event with its value at the beginning (Millar, 2014). In science, a frictional force is the force that results whenever two surfaces move across each other in opposite directions. Teacher B's response was to inform learners that friction is a force. Given that most learners struggle with understanding the concept of *force*, the researcher doubted whether defining friction as a force would have assisted learners to conceptually understand why friction cannot be an explanation for the difference in kinetic energy during an inelastic collision.

4.2.1.2 Teachers' use of everyday words as science concepts

As per research question 1, everyday English words are also used as science concepts. Unless learners are made aware of the new meaning that words like *energy*, *impulse* or *momentum*, to name but a few, assume when used in the science classroom, they might struggle to achieve grade level understanding. Following is an analysis of the manner in which the two teachers in this study created awareness about the changed meaning of words when used as *science concepts* in the Physical Science classroom.

Teacher A

Table 4.4 below is an analysis of Teacher A's use of technical words as *science concepts*. The following science concepts, under the knowledge area of Geometric Optics, were identified from the Doc Scientia textbook: reflection, speed of light, refraction, Snell's law, critical angle, total internal reflection, refractive index, Normal, angle of incidence, angle of reflection and angle of refraction. As is the case in most science classes, each of the abovementioned concepts was explained. Table 4.4 therefore does not have a column for words not interpreted as was the case for words used in a science context. However, only Snell's law and angle of refraction could be categorised as explicit interpretations. Explanations of the other concepts were categorised as implicit interpretations since Teacher A mostly provided definitions with very little elaboration that could aid conceptual understanding. Most of these concepts contained words that, in themselves, also needed explanation. This created the danger that very few learners could possibly conceptually understand the definition of the concepts.

The definition of the word *normal* was given as an imaginary line drawn perpendicularly to the surface. When Teacher A drew an incident ray, a normal and a reflected ray, a learner asked if the normal is not imaginary. That learner interpreted imaginary as something that should not be appearing in the sketch which, in turn, might indicate that the learner also did not know that the light rays were also just representations and not concrete.

Table 4.4 Word as science concepts as used by Teacher A

Investigating teachers' use of *technical words used as science concepts*			
Explicit Interpreting		**Implicit Interpreting**	
Word	**Text**	**Word**	**Text**
Angle of refraction	The angle of refraction is the angle between the refracted ray and the normal ne?	reflection	Reflection is when a shiny and smooth surface like for example like a mirror will reflect, **I know I am not defining it**, will reflect light in a regular way
		Speed of light	The speed of light is constant in a medium and number two it is a very, very important thing it is that the speed of light in a vacuum, is 3 by 10 to the exponent eight meters per second
Snell's law	So then that kind of relationship where you've got the sine of an angle of incident it's directly proportional to the sine of an angle of refraction its referred to as your Snell's law.	Refraction	What is refraction? Refraction ne? Refraction is the bending of light as it moves from one medium to another medium with a different optical density ne? Optical density ok? So that definition is worth 2 marks ne? So make so you come up with a refraction. Ok? I know on top of optical density we have to define what is optical density
		Refractive index	Right by definition the refractive index symbolised by small n is the ratio of the speed of light in air to the speed of light through another medium
		Normal	The normal, so the normal by definition is an imaginary line at 90 degrees to the surface of the mirror
		Angle of incidence	the angle of incidence, normally as I said is a phi with an i is the angle between the incident ray and the Normal ne?
		Angle of reflection	angle of reflection it's a phi with an r ne? Is the angle between the normal and the refracted [reflected] ray ok?
		Total internal reflection	But immediately when it goes into it change from being what Critical to what? Total internal refraction ... reflection.
		Critical angle	This one is a critical angle ne?
		Optical density	Right what is optical density? Optical density it's a measure of the speed of light or other electromagnetic waves through a medium ne?

The tendency of definitions to be embedded in other concepts is what Halliday (1993) referred to as "interlocking". The following was Teacher A's definition of refraction:

> *T: What is refraction? Refraction ne? Refraction is the bending of light as it moves from one medium to another medium with a different optical density ne? Optical density ok? So that definition is worth 2 marks ne? So make sure you come up with a refraction. Ok? I know on top of optical density [refraction] we have to define what is optical density*

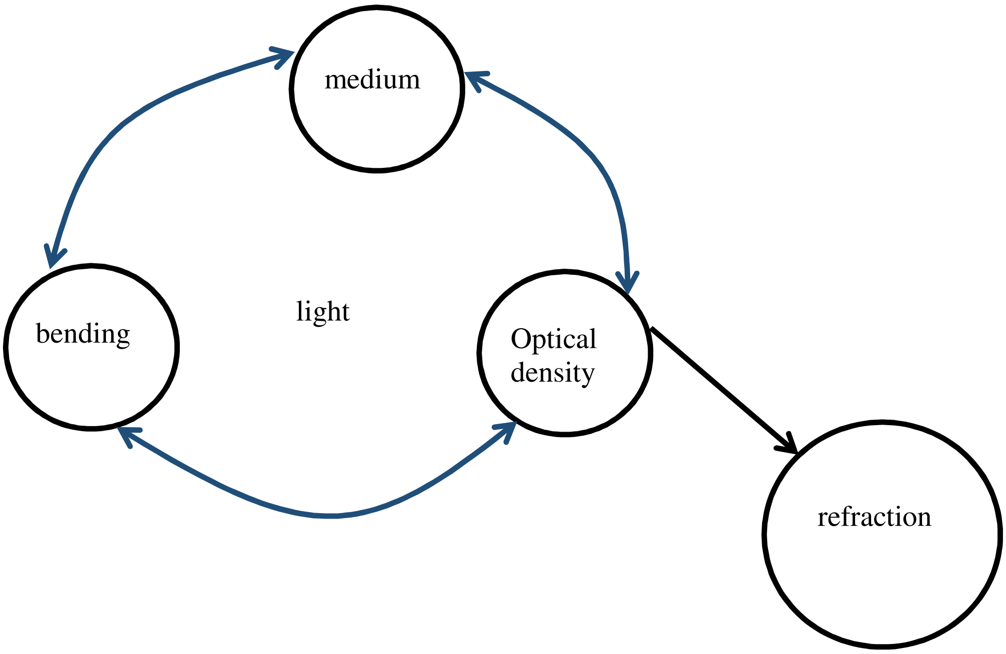

Figure 4.1 Adaptation of Halliday's interlocking definitions of four technical terms

Here *bending*, *medium, refraction* and *optical density* form a series of interlocking definitions (Halliday 1993). The interdependence is demonstrated schematically in figure 4.1 above. Bending, medium and optical density are used to define each other assuming that the meaning of light is already established. Refraction is defined by reference to the previous words *bending*, *medium* and *optical density*. The fact that the majority of the concepts introduced by Teacher A were only implicitly explained does lead to a concern that the teacher's use of language is generally incomprehensible to the learner.

Teacher B

Table 4.5 below is an analysis of Teacher B's use of everyday English words as science concepts. Momentum, change in momentum, Newton's first law, Newton's third law, conservation of momentum, elastic and inelastic collisions, impulse, Newton's second law, impulse momentum theory and kinetic energy were the science concepts under the knowledge area Mechanics that Teacher B discussed.

Teacher B ensured that he explained all science concepts to his learners. He deliberately focused on formulae as definitions and, in so doing, avoided the dilemma that Teacher A experienced when he tried to define science concepts with definitions that were riddled with new words that also needed explanation.

Table 4.5 Word as science concepts as used by Teacher B

Investigating teachers' use of *technical words used as science concepts*			
Explicit Interpreting		**Implicit Interpreting**	
Word	**Text**	**Word**	**Text**
Inelastic collision	Now guys, the idea here though is that when you do the calculations of kinetic energy for the objects colliding, you are then comparing the two kinetic energies. In our situation here, the two kinetic energies are not equal. So this type of collision we are going to call it inelastic collision. Inelastic collision. So what is inelastic collision? This is when the two objects collided the energy before is not equal to the energy after.	Momentum	T: What is momentum? L: mass times velocity T: Yes, exactly, mass times velocity
		Newton's second law i.t.o. momentum	If you remember, we did Newton's second law in terms of momentum and we've got fnet is delta p divided by delta t. That is Newton's second law of motion law in terms of momentum
		impulse	So fnet delta t is called the impulse
Elastic collisions	T: What is the opposite of that? LL: Elastic! T: Elastic collision. In elastic collision Ek before will be equal to Ek after the collision	impulse momentum theory	T: …. It therefore means that one can easily write that fnet delta t which is the impulse is the same as mvf – mvi isn't it? Because mvf – mvi is delta p, fnet delta t is our impulse. So this is called the impulse momentum theorem
		Kinetic energy	T: Who remembers the formula to calculate the kinetic energy? You did this last year! L: Sir! Exactly sir! T: ok Let me remind you Ek is half mv squared where m – should be in kg, v –is the speed in m/s and of course when we measure energy we are going to measure it in Joules. This is the formula that we are going to use.
		Change in momentum	And earlier on we did the change in momentum, remember? Change in momentum is equals to mvf – mvi.
		Conservation of momentum	T: Ok. Ok what do you say? L: Total linear … momentum in an isolated system remains constant T: Its fine, I can see they reading from their notes. All right let's move on

Teacher B's classroom talk was therefore generally very eloquent but nonetheless difficult to conceptualise hence the researcher concluded that the explanations could also be regarded as implicit. Teacher B demonstrated that it was possible for learners to do Physical Science without really conceptually understanding the work. By concentrating on the formulae that represented definitions of the physics concepts, Teacher B showed the learners how to answer Physical Science questions in a test or an examination. However, it was clear that this approach to learning came with its own set of problems. The researcher observed that learners found it very confusing to distinguish between the formulae for momentum, conservation of momentum and rate of change of momentum, to name but a few examples. Teacher B also needed to repeatedly remind learners which formula to use when solving a particular concept. The fact that learners could not remember from one topic to the next clearly pointed to the low retention of science knowledge.

The excerpt below is another example that demonstrated Teacher B's formulaic approach to science teaching at the cost of conceptual understanding.

> *T: Remember Newton's second law, we did that other Newton's law the first one which has acceleration and mass. We did Newton's second law in terms of momentum so what they are looking for here is the one in terms of momentum.*
>
> *L_2.: So they don't want momentum to be the subject of the formula?*
>
> *T: No, Fnet equals the rate of change of momentum.*
>
> *L: So net force is equal to rate of change of momentum?*
>
> *T: [nods]*

Teacher B totally missed the fact that the learner understood the meaning of the words "Newton's second law in terms of momentum" as saying "make momentum the subject of the formula". Whatever difficulty the learner might have with the science concept is compounded by the wrong meaning that the learner assigned to the words "Newton's second law in terms of momentum". A general unawareness of the potential for confusion that science words have for learner understanding complicates the learning of science.

4.2.2 Analysing the approaches to vocabulary building of the two teachers

Table 4.6 below considers the vocabulary building of the two teachers based on the criteria set out by Bravo et al. (2006). The four criteria (see table), adapted from Bravo et al. (2006), were used to assess teachers' vocabulary building.

When considering if teachers targeted a focused set of science words, it was found that this was true for everyday English words that were *used as science concepts*. However, most of these words were categorised under implicit explanations implying that the teacher mostly assumed the learner would derive meaning from the given definition or equation. The teacher showed little concern for familiar words used *in a science context* that assume different meaning when used to convey science. The possibility that the learner might still have the everyday understanding of these words was quite real as the teachers did not emphasise the changed meaning as was discussed earlier on with the example of the words *bend/bending*.

Another means of exposing learners to science terms is by displaying words against walls in the classroom. The classrooms of the two teachers were generally language poor in that there was very little display of relevant words in the classrooms hence exposure through multiple modalities was also very limited. Teacher A's classroom walls were covered with posters but none of the posters had any bearing on what was taught in the classroom at that stage neither were there any mention made to any words displayed on the posters.

Table 4.6 Analysis of teacher awareness of polysemy (Adapted from (Bravo et al., 2006))

Criteria	Teacher A / Motivation		Teacher B / Motivation	
Targeting a focused set of science words	Yes No	Words as science concepts Words in a science context	Yes No	Words as science concepts Words in a science context
Providing multiple exposure to science terms through multiple modalities	No	Teacher A did not go beyond giving definitions	No	Teacher B focused on using science terms in equations
Systematically and explicitly introduce terms in semantically networked way	No	Words were not linked semantically	No	Words were not linked semantically
Making connections between targeted words and words learners already know	No	Prior word knowledge did not form a basis for vocabulary teaching	No	Prior word knowledge did not form a basis for vocabulary teaching

None of the last two criteria in Table 4.6 above were evident in either teacher's teaching practice. The teachers mostly followed the order of the textbook which does not necessarily link concepts for their relatedness or differences. As mentioned earlier, vocabulary building was out of focus in the two science classes observed.

4.2.3 Teachers' awareness of polysemy as communicated during the interviews

The purpose of the interviews was to establish if the teachers' personal views concerning vocabulary building with a specific emphasis on polysemy corresponded with their classroom practice. Below is an excerpt where the researcher wanted to know about the awareness of Teacher A concerning his experience of difficulty that learners had with assigning correct meaning to science words.

> *R: All right Teacher A I've got a few questions that I wanted to ask you about the observations that I made in your classroom. If you can remember my topic was "Polysemy and context" where Polysemy referred to the many meanings that a particular word can have. And I was particularly interested, whilst sitting in your classroom, at how you made sure that you and your learners shared the same idea for a particular word. So one of my questions that I actually wanted to ask you is: Do you find or do you think that it does happen that your learners will carry meaning into the classroom and that that meaning could be different from what is actually intended in your actual lesson? Meaning of words.*
>
> *T: Yes that comes out. It is a challenge in most of the time you might be giving that is a definition or maybe an explanation but learners, in terms of understanding, they come with their own meaning. The only way of making sure that we share the common same understanding of a word, as you have seen, I made sure that I'll put it on transparency; I'll write its specific meaning and also put an emphasis on it that we understand it the same.*

On the polysemous nature of words, Teacher A was convinced that measures like writing the word so that learners could see the actual spelling of the words were enough to ensure that common understanding was maintained. The researcher has a strong sense that the teacher was referring to homophones rather than polysemy. Homophones are same sounding words like *bear* and *bare* whereas homonyms are the same word with unrelated meanings (for example, *fly*). The benefits of writing words down when used in conversation are far more advantageous for homophones than for polysemous words. An example of emphasising, that was apparent from the observation, was the tendency to break words up into their syllabi as in Re-frac-tion when saying them. None of the above efforts can really serve as guarantee that learners understand the intended meaning.

Teacher B appeared to be aware that everyday words assume specialised meaning in the science classroom. However, his word use in the classroom did not make this evident. Below is his answer on the issue of polysemy. The researcher gave a background of her study and the incident is related from the point where the following question was asked:

R: Do you find in your own teaching that it becomes necessary to focus on words and the meaning that you actually want your learners to attain in a particular lesson?

T:… Now, before one starts to teach weight, if you are to like I ask my boys here, what is your weight? What they will actually give me is not the weight but is their mass so we then have to deal with that. Like I mean in everyday they talk about losing weight, losing weight or what is my weight and they use the mass scale to get their weight and not knowing that, in fact, what they are actually measuring there is their mass and then you can have a mathematical equation to calculate to get the weight. And also in the lesson that we had about momentum, they seem to sort of have an idea oh about momentum but they are not sort of using it in the physics sense in the physics way. They just say oh when I gain momentum but exactly what that one is ...? So yes indeed there are lots of sort of words that one needs to explain further other than the everyday sort of ...

Teacher B convincingly demonstrated how, by using analogies, it was possible to create conceptual understanding to the extent that the researcher is of the opinion that Teacher B was aware of the polysemous nature of science words. The following excerpt serves as evidence:

T: … weight, for example, that when we start talking about the planets, and weight in other planets, weight in the moon … knowing that their mass will not change where ever they go but then their weight will change … it's good to know the difference between mass and weight … also momentum when you sort of have the mass of the truck, the mass of the car and the speed and if they are moving at the same speed but they have got different masses so the other one will have more momentum than the other one. So the stories make them to be more interested … differentiate between the everyday talk and the real meaning in science.

From the above discussion, both teachers appeared confident that they were conscious of the potential for confusion that science words posed in the science classroom. It was clear from the interview that vocabulary building as a focus for both teachers was considering technical words *used as science concepts* and very little focus was given to the non-technical words *used in a science context*.

The teachers' joint approaches to vocabulary building and creating an awareness of the polysemous nature of words, as presented during the interviews, covered all the criteria as stipulated by Bravo et al. (2006) in Table 4.6 above. "Systematically and explicitly introduce terms in semantically networked way", was the only criteria that was not explicitly communicated by the teachers. This omission could possibly be attributed to the fact that the researcher did not explicitly ask how they introduced terms in the science classroom. Table 4.7 below summarises the comparison of classroom practice and opinion about own practice of the two teachers regarding the polysemous nature of words.

Table 4.7 Teacher awareness of Polysemy

Research Concern	Participant	Instrument	
		Observation	Interview
Awareness of Polysemy	Teacher A	No	No
	Teacher B	No	Yes

The contradiction between classroom practice and personal awareness of polysemy in Teacher B's case may partially point to a teaching practice that uses the enacted curriculum with examination preparedness as its sole aim. The procedural nature of his teaching seemed to indicate that Teacher B seemed to have been focused on teaching his learners how to pass the examination (Khisty, 1993). Anecdotally, where a number of science teachers tend to call the unit of impulse Newton seconds, Teacher B was almost clinical in his execution of the words Newton second. However, none of his learners picked up on the difference as he never attempted to correct any of them when they referred to the unit of impulse as Newton seconds. Unless learners are explicitly asked to write the full meaning of the unit N.s., it is highly unlikely that their unawareness that it is actually Newton second would jeopardise them in a test or an examination.

Teacher A had an interesting approach whereby he would always remind learners that the familiar word that he was using in the science classroom did not have the everyday meaning that learners might want to assign to these words. Below is such an example:

> *T: … plus we have Ruby not the one in Generations* [Popular soap opera on television].

The concern that the researcher has with this approach is twofold. Firstly, the words that Teacher A explored in this manner are all words that Wellington and Osborne (2001) label as level one words. They describe these types of words as identifiable, observable and real. A learner will therefore have very little difficulty with a conceptual understanding of these words. The second concern is that to tell the learner what a particular word is not, does not necessarily guarantee that learners would understand what that word is, especially when it involves concept words. Below is convincing proof of the inadequateness of this teaching approach:

> *Teacher A: Right, one thing that we need to take note of with light. I know some of you might relate to light in terms of the Genesis factor ne? In the Bible, where it says, in the*

beginning, it was the word the word was with God and then He said let there be light. This is the physics light that we will be talking about.

The researcher is of the opinion that the above approach will only manage to create more questions in the mind of the learner rather than helping them to come to the expected understanding of the meaning of *light*.

The discrepancy between their practice and their expressed intend during the interviews, confirms Christie's (1998) assertion that subject teachers simply do not know how to assist learners in understanding the language of school science (LSS).

4.2.4 Implications for learning school science

An episode from Teacher A and Teacher B's classrooms respectively is used to demonstrate implications for learning Physical Science.

Teacher A

Below is a teaching episode in Teacher A's classroom that reflects the importance of ensuring that learners understand the meaning of words in order to successfully learn or teach science. Teacher A gave learners the values of the speed of light in different mediums. The mediums of interest, in this case, were water and ice. At the point when learners wrote the values down, there were no questions from the learners' asking why speeds were different in different mediums.

T: Right the speed of light in air is 3,0 by 10 exponent 8 units m.s^{-1} , in ice it's 2,9 by 10 to exponent 8 m.s^{-1}, in water, it's 2,26 by 10 exponent 8 m.s^{-1}…

It was only when Teacher A gave the definition of a refractive index as a ratio of the speed of light in air to the speed of light in a medium that a learner was surprised by the fact that the refractive index of the two mediums was, in fact, different.

T: Number one, calculate the refractive index of the following: one of air, number two of ice, number three of lebati,….

L: The refractive index of ice and water is not the same?

The learners' surprise is indicative of the fact that the learner did not understand the concept of optical density. The teacher's explanation of what optical density is was categorised as implicit. He merely stated optical density as a measure of the speed of light through a medium. This was never related to the refractive index of light in water and ice or any other medium, for that matter. Teacher A's response to the learner's discovery that ice and water did not have the same refractive index, is worth mentioning:

> *T: It won't not be the same. When water becomes ice it changes its property ne? If you have ice, can you see through ice? …*
>
> *L: It's just the Physical properties that changes?*
>
> *T: Yes. Change in Physical not Chemical properties it's still H_2O. But the bonding there is completely different ok? So you'll do for me this work. Then tomorrow ... [inaudible]. But we will do Snell's law and after Snell's law we will be able to jump to chemistry.*

The teacher's reference to the transparency of water and the opaqueness of ice are all factors related to the optical density of these two mediums. Since the word *optical density* has no meaning for the learner, he will remain confused by the physics terms and may, as a coping strategy, merely memorise the procedures needed to score full marks for a question requesting the calculation of the refractive index of ice and water.

Teacher B

It was very difficult to fault Teacher B's vocabulary use in terms of its correctness. However, he also ignored the importance of vocabulary building in the science classroom. Following is an excerpt of an episode where Teacher B made careful selections of when to use speed and velocity whilst talking about kinetic energy and momentum.

> *T: …Ok let me remind you E_k is half mv squared where m – should be in kg, v – is the <u>speed</u> in meters per second and, of course, when we measure <u>energy</u>, we are going to measure it in Joules. This is the formula that we are going to use.*
>
> *T: So one can ask this: How does the energy link to the <u>momentum</u> we were doing? The answer is simple. Consider this two objects which are moving. … Now if you can check carefully here, I'm giving you first the <u>velocities</u> before they've collided and then we've got the velocities after they have collided.*

Teacher B continued explaining how to determine if collisions are elastic or inelastic and, at the same time, made careful selections of when to talk about speed or velocities**.** Twenty minutes into this lesson, a learner asked if energy was a scalar or a vector. When he posed the question to the rest of the class, a whole debate erupted. Clearly, none of the learners noticed that Teacher B was using the word *speed* when he talked about energy and *velocity* when he talked about momentum. One learner considered the equation for kinetic energy and concluded that since *v* was squared, energy will always be a positive value, making it a scalar. Teacher B accepted this as an adequate explanation for whether energy was a scalar or a vector. The researcher is of the opinion that this link between energy being a scalar and the formula for kinetic energy obscures the appropriate use of the words *speed* and *velocity* and the subsequent connection with magnitude. Shortly after that, a learner asked the following question:

> *L: Sir, when you said that your <u>energy</u> is equal to mass in kg and <u>velocity</u> in metres per second, ok...*

Teacher B did not correct the learner although the teacher deliberately used *speed* when he had to define kinetic energy. Table 4.8 below is a representation of the conceptual understanding that was not yet established for this particular learner.

Table 4.8 Word links for speed and velocity

Speed	→	scalar	→	no direction	→	magnitude	→	calculate energy
Velocity	→	vector	→	choose direction	→	calculate momentum		

Learners will not have the science understanding of speed and velocity and will continue to interchange these meanings as is the case in their everyday speech. The following excerpt is just one of numerous occasions that served as evidence that a focus on vocabulary will ensure conceptual understanding that is critical to ensure that learners perform on grade level. Below is an excerpt where Teacher B marked learners' exercises and expressed disappointment with the poor understanding of scalar vector concepts:

> *T: … The correct answer there is 1,44 and again in this one, they are asking for momentum, not the magnitude of momentum. So, most of you did not even write the direction. So, your answer should be 1,44kgm/s towards the wall. So if you don't write direction, remember we subtract one [mark].*

From the discussion in this section, it became evident that the changed meanings that words assume when used in a science context were generally ignored by both teachers. The teachers seemed to assume that the science classroom context was sufficient to ensure that the intended science meaning is communicated when using those familiar words. Concept words that also have everyday meanings were explained on a very superficial level either as formulae that focus on how to get the answer or definitions that were riddled with unknown words. In both situations, learners were assumed to make sense of what the teacher was saying. Irrespective of how well teachers model the language, it is important that they explicitly teach the reasons for their word choices as learners are unlikely to come to the understanding by themselves. Their perceived effectiveness of communicating the meaning of science words as conveyed during the interviews, was in stark contrast to the observed general absence of a display of understanding of the meaning of those words, from the learners' side.

In conclusion, given the number of unexplained words and concepts that learners were faced with in the two science classrooms, many science learners may identify with Alice's expressed confusion when she read the strange words in the poem "Jabberwocky": "Somehow it seems to fill my head with ideas – only I don't exactly know what they are!" (Carroll, 1917).

4.3 On a language level

Research question 2 concerned itself with teachers' use of language as a semiotic system. Lemke (1990, p. 183) gives the following definition of semiotics.

> Semiotics is the study of all systems of signs and symbols (including gestures, pictures, even hairstyles) and how we use them to communicate meanings.

The meaning construed by a certain text is a function of the grammatical choices made by the writer/speaker. What follows is a report on the teachers' language use in the science classroom. The common understanding referred to in the research question is achieved if the teacher successfully manages firstly, to explain to learners why science text looks the way it does and secondly, to clarify the meanings that they should/can derive from a science text based on the specific language construction.

4.3.1 Evidence of teachers' use of language as a semiotic system

Thinking is a process that is realised through semiotic activity and symbols are one of the semiotic tools used to understand concepts (Kress, 2001). Mbewe (2014) states that these symbols used to construe meaning can only do so when interpreted by individuals. The researcher is of the opinion that the teacher need to play the role of enculturating learners into interpreting the symbols in the same way as the science community would.

What follows is an account of Tshepo, a learner in Teacher A's classroom, as he struggled to understand the relationship between Snell's equation and its graph. The interest in this episode lies in the semiotic representation of Snell's law through the use of oral language, written language, a mathematical equation and graphical representation.

Tshepo's struggles with dependent and independent variables

This episode was observed in Teacher A's classroom. In Table 4.1, the researcher indicated that the words *dependent* and *independent* were explicitly explained by Teacher A. His explanation was prompted by a question from a learner, Tshepo, who wanted to know which between the angle of incidence (θ_i) and the angle of refraction (θ_r), the dependent variable was. At that stage Teacher A just finished drawing the graph of θ_i vs θ_r with θ_i on the y-axis and θ_r on the x-axis. His explanation used the fact that the independent variable was the variable that can be chosen whereas the dependent variable was a result or outcome of the initial choice. Tshepo had no problem with that explanation. His confusion came from the fact that Teacher A's independent variable was drawn on the y-axis whereas, in the mathematics classroom, the independent variable is represented on the x-axis when drawing a graph. This became evident when Tshepo drew his graph of $sin\theta_i$ vs $sin\theta_r$ on the board. The episode is related from the instance where Tshepo drew the graph:

L: So our dependent variable is the reflected one.

T: Ja

L: … so it's this one. So it depends on this one the incident [putting $\sin\theta_i$ on the x-axis].

Teacher A did not comment on the fact that Tshepo was using the x-axis for his incident angle despite the fact that he (Teacher A) used the y-axis for the incident angle when he first drew the graph of θ_i vs θ_r and subsequently that of $sin\theta_i$ vs $sin\theta_r$.

One can represent Tshepo's semiotic system for dependent and independent variables as in Figure 4.2 below. Tshepo has assigned x-axis to independent variable and y-axis to dependent variable. The validity of this meaning making system was confronted in the science classroom when Tshepo noticed that his teacher did not follow the convention.

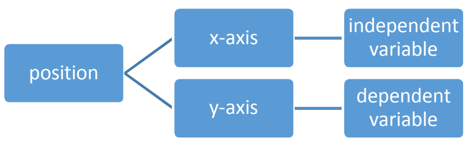

Figure 4.2 Tshepo's semiotic system

Figure 4.3 below represents Teacher A's semiotic system which is more in line with that of the science community. Teacher A does not assign dependent and independent to any specific axes as he is aware that the equation will change accordingly. It is unfortunate that Teacher A did not seize the opportunity to address the defect in Tshepo's system as this struggle to relate the different representations to the same meaning is identified as one of the characteristics of LSS that sometimes obscures science meaning from learners (Lemke, 1990).

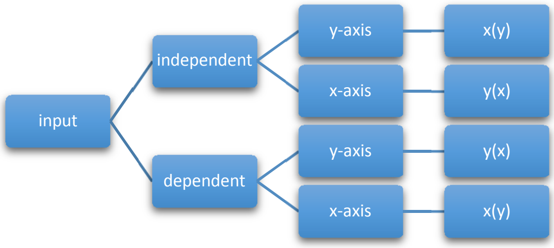

Figure 4.3 Teacher A's semiotic system

The following is how Teacher A used the graph to derive Snell's law.

> *T: … So there what we need to take note number 1 … you have to state that the graph is a straight line graph ne? ... Then being a straight line graph, the gradient is a constant so … It confirms that the sine of the angle of incidence is directly proportional to the sine of the angle of refraction. So, basically, the second point … the gradient it's a ratio, … between … the sine of the angle of incidence and the sine of the angle of refraction.… And this is known as… the Snell's Law of refraction ok?*

Teacher A successfully unpacked the noun group *straight line graph* to assist his learners to come to the following understanding: the gradient is constant and can be given as $\frac{sin\theta_i}{sin\theta_r}$. Teacher A was not explicit in informing learners that the gradient was given as $\frac{\Delta y}{\Delta x}$ as this might have kept a stronger link between the graph and the equation.

Teacher A's explanation continued:

> *T: So the Snell's law of refraction as it is stated in terms of the relationship there it says the sine of the angle of incidence on the sine of the angle of refraction its equals to the index ne, refractive index of refraction on refractive index of angle of incidence. So if you write it in simple this it will be, it will be refractive index multiply by the sine of angle of incidence equate to refractive index the sine of angle of refraction. So there it is [Inaudible] ne? Then define all.*

A big jump from gradient $= \frac{sin\theta_i}{sin\theta_r}$ to $n_i sin\theta_i = n_r sin\theta_r$. Teacher A followed the textbook closely when he taught Geometric Optics. Science textbooks tend to leave information that should be made explicit, implicit. It generally requires much more from the reader to come to the intended meaning of the text than getting information from a teacher's oral explanation. The learner needed to know the experimental evidence $\frac{sin\theta_i}{sin\theta_r} = \frac{n_r}{n_i}$

Tshepo's struggles came from the fact that he did not realise that the shape of a graph was a direct link to the equation it represented. He will, in all likelihood, also not recognise the simplified form of the straight line equation $(y = mx)$ is in Snell's law, $n_i sin\theta_i = n_r sin\theta_r$ if $(n_i = 1)$. He could therefore not explain to himself why the teacher placed $sin\theta_i$ on the y-axis. Deacon (1999) explained that the choice of $sin\theta_i$ on the y-axis was merely a choice of convenience. However, in the absence of any attempts from Teacher A to relate the graphical representation with the equation of Snell's law, Tshepo did not realise that, should he insist on keeping $sin\theta_i$ on the x-axis, his equation would have to change to $sin\theta_r = \frac{1}{n_r} sin\theta_i$ for a situation of light rays travelling from air $(n_i = 1)$ to another medium. Tshepo might struggle to remember Snell's law and erroneously write it as $sin\theta_r = n_r sin\theta_i$. Alternatively, he might commit the equation to memory and through rote learning answer questions in tests or examinations.
The analysis of Teacher A's derivation of Snell's law from a linear graph demonstrated that, by having an awareness of the semiotic nature of LSS, teachers can interrogate their own explanations to identify which modality is needed to complete the understanding of a science concept. The above episode highlights that if they are aware of the semiotic nature of LSS, teachers can assist learners with linking the correct meaning between the various presentations that eventually communicates the same concept.

Following is an episode in Teacher B's classroom when he introduced the impulse-momentum theorem.

Teacher B

Questions related to this topic required learners to calculate the impulse and the change of momentum. Almost every learner failed to see from the given equation $f_{net}\Delta t = \Delta p$ that once they have calculated the impulse $(f_{net}\Delta t)$ then they automatically had the answer for the change in momentum. In other words, the learners did not have the same meaning for the equal sign as that held by teachers and scientists. The researcher went back to look at the manner in which Teacher B introduced the equivalence of the two concepts. An excerpt of the episode is provided below.

T: All right, grade 11, I now want to take you back to Newton's second law of motion in terms of momentum. If you remember, we did Newton's second law in terms of momentum and we've got fnet is delta p divided by delta t. That is Newton's second law of motion in terms of momentum. The net force is equal to the rate of change of momentum. Now, if I write it in this way fnet delta t equals to delta p, will that be correct?

L: Yes Sir

T: That will be correct. And this is what we call an impulse momentum theory. So fnet delta t is called the impulse. fnet delta t is called the impulse remember delta p that is the change in momentum. And earlier on we did the change in momentum, remember? Change in momentum is equal to mvf – mvi. So it therefore means that ... [Interruption – knock on the door]. [After interruption] Now, we know that change in momentum is mvf – mvi. It therefore means that one can easily write that fnet delta t which is the impulse is the same as mvf – mvi isn't it? Because mvf – mvi is delta p, fnet delta t is our impulse. So this is called the impulse momentum theorem.

Table 4.9 below shows the teacher's actual words in column one. The second column has the formulae that Teacher B wrote on the board whilst explaining. The last column represents the purpose of the equal sign at that particular instance which could have been either to define, to solve or to state equivalence.

From a systemic functional linguistics point of view, the statement, *impulse is change in momentum*, is a relational clause. If learners are taught to recognise relational statements, they would also know that these statements are reversible. That means that impulse and change of momentum are the same thing. Although all statements are relational in Table 4.9 below, the manner in which the questions were asked led the learners to interpret specific questions in particular ways. Typically, sentences that say "is equal(s) to" are interpreted as "solve by substituting in the right hand side". Statements that contain the word *is* or *is called* are interpreted as definitions. Hence when Teacher B expected his learners to interpret "fnet delta t is our impulse", it was difficult to see the reversibility of the statement.

The researcher posits that the meaning intention of the teacher was not always clear to learners considering that the two most common interpretations by learners of the equal sign are to see it as a "do something" or a "now follow the answer" sign (Powell, 2014). Much overlooked by learners, is the meaning of the equal sign that communicates an equivalence relation. Researchers (Mbewe, 2014; Powell, 2014) are of the opinion that teachers should explicitly teach the notion of "sameness" between the left hand and the right hand side of the equal sign. Most of the questions that were posed during the lesson required learners to use equations to solve or define concepts.

Table 4.9 Teacher talk around the equal sign

Teacher words	Mathematical representation	Meaning of equal (=) sign
fnet **is** delta p divided by delta t	$f_{net} = \frac{\Delta p}{\Delta t}$	Define f_{net} Now follow the answer for f_{net}
The net force **is equals to** the rate of change of momentum.	$f_{net} = \frac{\Delta p}{\Delta t}$	Solve for f_{net} Do something
fnet delta t **equals to** delta p	$f_{net}\Delta t = \Delta p$	Solve for delta p Do something
fnet delta t **is called** the impulse.	$\underbrace{f_{net}\Delta t}_{\text{Impulse}} = \Delta \text{p}$	Define impulse Now follow the answer for impulse
delta p that **is** the change in momentum	$\underbrace{f_{net}\Delta t}_{\text{impulse}} = \underbrace{\Delta \text{p}}_{\text{change in momentum}}$	Define momentum Now follow the answer
Change in momentum **is equal to** mvf minus mvi	but $\Delta p = mv_f - mv_i$	Solve for delta p Do something
that fnet delta t which is the impulse **is the same as** mvf minus mvi isn't it?	$f_{net}\Delta t = mv_f - mv_i$ Lifting his shoulders whilst asking. Hands next to the body open palms up.	State equivalence Gesture saying "obviously!"
Because mvf – mvi **is** delta p, fnet delta t **is** our impulse!	Pointing to lhs of equation $\underbrace{f_{net}\Delta t}_{\text{impulse}} = \underbrace{\Delta \text{p}}_{\text{change in momentum}}$ Pointing to rhs of above equation ending his sentence with an open hand palms up again and slight shrug of shoulders.	Re-emphasise what was communicated non-verbally

Earlier in this chapter, the researcher discussed the fact that the fact that teachers do not teach vocabulary understanding, compounds the difficulty of understanding science concepts. The fact that Teacher B did not adequately focus on explaining the science meaning of *impulse*, apart from an equation, could very well have contributed to the lack of understanding amongst learners. However, the researcher is of the opinion that learners possibly could have answered the third type of question if they had a relational understanding of the equal sign. That is, if learners interpreted the equal sign as indicating an equivalence relation, a sameness, between $f_{net}\Delta t$ and $mv_f - mv_i$. Although Teacher B explicitly said "*It therefore actually means that one could actually write that fnet delta t which is the impulse* ***is the same as*** mv_f *minus* mv_i *isn't it?*" whilst writing: $f_{net}\Delta t = mv_f - mv_i$ on the board (see Table

4.9), he used non-verbal communication when he shrugged his shoulders, arms outstretched, hands opened, palms pointing upwards. This important communication went over the learners' heads and they did not benefit from the multimodal communication as Teacher B did not highlight the equivalence relationship of the equal sign. Learners therefore did not realise the significance of Teacher B's decision when he introduced the impulse momentum theorem, to use the words *the same as* instead of *is called*, or *equals* as he was doing prior to this point. This clearly demonstrated that the learners might have incomplete meanings assigned to the equal sign. Explicit teaching of the various modalities used to communicate science concepts as part of teachers' classroom language may assist learners.

When corrections were done, the following day, confusion was rife in the classroom:

> *T: What is the average change in momentum of the car? Number c I saw some of you started calculating the change in momentum. If you can recall from yesterday we said that impulse, in order for you to calculate impulse, it is fnet delta t, that is, impulse. But we also found that impulse is the same as change in momentum. So whatever you've got your impulse it will be the same as the change in momentum. Ok, it's the same thing! So that's why you can now say fnet delta t* ***is*** *equal to mvf minus mvi. These are all impulse. Impulse* ***is*** *change in momentum. So if you can check question B. Let's go back to question B. It says what is the impulse exerted on the car? And we got 24000Ns west. Then C asked you what is the change in momentum of the car? Hallo, it is exactly the same thing. You didn't even have to calculate.*
>
> *L: Sir isn't it the initial momentum though Sir, of the car? Before it hits and after its now? So you have the change of those?*
>
> *T: Yes, but what they are trying to say, is once you have calculated impulse, impulse is the same as the change in momentum.*
>
> *L: I don't get it.*
>
> *L: I also don't get it*
>
> *T: You don't get that one right?... In your calculations what did you get?*
>
> *L: Sir, can you go as far as then always say that impulse is the change in momentum?*
>
> *T: Yes, impulse is the change in momentum. So the first question number B asks you what is the impulse? The second question asks you what is the change in momentum? So from what we did yesterday, we said impulse is the same as change in momentum. So now impulse fnet delta t = mvf minus mvi, ok.*

The learner's resolve to commit this fact to memory did not stand him in good stead either as numerous occasions after this, Teacher B had to remind him that impulse was, in fact, the same as change in momentum. The persistence of this difficulty ruled out the argument that learners were simply unfamiliar with the equation. It also pointed to the fact that teachers cannot expect learners to understand concepts if telling is the only method of teaching. Teacher B obviously knew exactly what meaning he wished to convey in every instance that he was using the equal sign in his explanation. However, he was unaware that learners were not able to assign these changing meanings as it was never made explicit how he changed his language use to achieve that objective.

Lemke (2004) speaks of the academic register of science as a hybrid language in which meaning is also constructed using mathematical expression, visual representation and specialised actions. Equations and graphs are some of the representations used to communicate science. It was shown that the science communicated by the equations and graphs created confusion for learners which the teachers were mostly unaware of.

4.3.2 New way of seeing

Louisa et al. (1989) posit that common misconceptions found in pupils' work on heat "were embedded in the linguistic metaphors and analogies used by the teachers when discussing with the pupils" (p. 465). The study of Optics and Mechanics are also renowned for the misconceptions that learners can form when dealing with concepts embedded in these topics. It was very noticeable, given both teachers' years of teaching experience that neither spent any time addressing how the use of LoLT could lead to misconceptions.

Brookes and Etkina (2007) report that phrases like "force of bat on ball" contribute to learners concluding that force is a property of an object rather than the result of interaction between objects. Teacher B used these expressions numerous times in his teaching. Below is an extract on an example of *impulse* that clearly indicated learners' confusion regarding the meaning of the expression "impulse provided by or to an object" .

> *T: Calculate the momentum (*correcting himself*) calculate the impulse provided by the ball or to the ball*
>
> *L: To*

When Teacher B said *provided by the ball or to the ball*, he was not asking for a selection but implied that the forces were the same hence the magnitude of the impulse would be the same whether it was impulse provided to or by the ball.

By selecting to see the question as "calculate the impulse provided *to* the ball", the learner, indicated that he understood impulse as being a property of an object. Teacher B did not explain the meaning of the word *impulse* hence it was very likely that the learner had an everyday understanding of *impulse* namely “a sudden strong and unreflective urge or desire to act”. With such an understanding of the meaning of impulse and the fact that the LSS changed impulse from a *process* namely a change in momentum to a *property* of an object, common sense assigns the ability to act to the header and not the ball.

The teacher continued the discussion as follows:

> *T: we come to see that the forces are the same now. Calculate the impulse provided to the soccer ball. How will you do it?*

It is possible that the learner could fail to link Teacher B’s statement that the forces are the same to the teacher’s choice to continue and only talk about impulse ***to*** the ball. In the absence of him being challenged on his assumption that the correct sentence should state impulse to the ball, the learner could continue to have an everyday understanding of the meaning of *impulse* when used in the science classroom.

4.3.3 Nominalisation

Definitions in science are an example where nominalisation is often used. The difficulty that comes with nominalisation is the fact that, since it uses parts of speech and changes them to nouns, the original meaning might be hidden from the novice. To assist learners to understand the science meaning, it might become necessary for teachers to unpack the word or noun phrase. In the analysis of the teachers’ classroom talk, the researcher considered definitions used by the two teachers and looked at the unpacking that the teacher did in order to assist learners with obtaining the science meaning. Young and Nguyen (2002) suggested the following steps for explicit unpacking of a word or noun phrase:

- change the noun or noun phrase to the original verb or adjective
- if the result is some technical term, explain the meaning of that term.

Table 4.10 represents examples of nominalisation used by Teachers A and B.

Teacher A made far more use of nominalisation than Teacher B. This is because Teacher A’s language was very close to the language used in the textbooks. Teacher A wrote notes from a textbook onto transparencies that his learners then copied into their books. Teacher B used mostly simplified words and very few technical terms.

Table 4.10 Explicit or implicit unpacking of nominalised words or phrases

Teacher A	Teacher B
T: Reflection is when a shiny and smooth surface like for example like a mirror will *reflect…* • Explicit unpacking of nominalisation • No unpacking of technical term *reflect*	T: because the object is *stationary* • Because it is not moving, v = 0 [Explicit unpacking of technical term]
T: Then you show us how you make your *calibration*. Google it! • No unpacking	• T: Inelastic collision. So what is inelastic collision? This is when the two objects collided the energy before is not equal to the energy after[Explicit unpacking of nominalisation]
T: It is that it's *directly proportional*. As one increases also the other one increases *proportionally* ne • Explicit unpacking of nominalisation • No unpacking of the technical term *proportional*	T: net force acting *is inversely proportional* to the time. So the longer the time the less the force. • Explicit unpacking of nominalisation • No unpacking of technical term *proportional*
T: *relationship* between that is what? Your sine of theta, the sine of angle of incidence that is related to the sine of angle of refraction • Implicit unpacking of nominalisation • No unpacking of the technical term *relate*.	T: use the *conservation* of momentum. Momentum before collision equals momentum after collision • Explicit unpacking of nominalisation No unpacking of technical term *momentum*
T: Your *critical angle*. Critical angle is when a light ray in a substance is moving from a greater *optical density* into a substance of a lower optical density. (Level 1 only) • No unpacking	

It was reported in section 4.2.1.2 that Teacher A struggled to explain definitions in a manner that was not loaded with unexplained technical terms. At times, he seemed overwhelmed by the science language. Considering the suggestion by Young and Nguyen (2002) to unpack nominalisations, it becomes clear that such a strategy will benefit the teaching of definitions. Teacher A, as demonstrated in Table 4.10 above, was not helping his learners to successfully unpack nominalised words and phrases.

When looking at how the two teachers explained the terms *directly* and *inversely proportional* respectively, Teacher B skilfully avoided using words that needed explanation in a definition. This resulted in a smooth delivery even though learners in both teachers' classrooms might struggle to explain the meaning of *proportional*.

Learners in Teacher B's classroom were confronted with symbolic language which proved to be confusing and sometimes difficult to comprehend. He did not complicate matters with difficult technical language. It is ironic that the first additional language learners had to deal with the more technical nature of the science language.

This analysis was in line with the teachers' views during interviews. Teacher B felt that his language use was simple enough to accommodate all learners. The researcher interpreted this as meaning that Teacher B did not see the importance for learners to become familiar with the language of school science. It appears as if Teacher A believes that learners should learn to cope with the language of school science because he cannot make the concepts of Geometric Optics easier for them due to an absence of the vocabulary in their home language. Teacher B, on the other hand, experiences the LoLT as flexible enough to avoid the technical nature of LSS and focus on that which is appropriate for the examination. In both cases, learners are denied the opportunity to become enculturated in the language of school science.

4.3.4 Dense noun sentences

Halliday and Martin (1993) point out that it is not possible to separate the language from the subject matter itself as science is defined by the discourse it uses. One of the major differences between everyday language and science language is the lexical density of the science language. The words that refer to content or factual knowledge in one sentence tend to be comparatively higher in scientific speech than in everyday speech.

Following are excerpts taken from lessons taught by both teachers. The excerpts compared well in the sense that they were about the same length, hence, learners needed to concentrate for a similar amount of time to make sense of what was said. The researcher looked comparatively at the number of content words (nouns) that were used by each teacher and subsequently calculated the lexical density as a ratio of total content words used divided by the number of clauses.

Teacher A

Right by definition the refractive index symbolised by small n is the ratio of the speed of light in air to the speed of light through another medium. For this one, it is straightforward ne? Just put the formulae and with your calculator you'd work for me the refractive index of those substances that I've gave you their ratios yesterday. So the formulae that you use there is refractive index equates to the speed of light in air divided by what? the speed of light in a medium. But normally we don't want this formulae in this format. The simplest format is your n equates to your c that's the speed of light, divided by the velocity of another medium ne? So for yesterday I know I gave you] the refractive index of the following.

Lexical density: ratio of nouns to clauses (2.73)

41 nouns in 136 words

15 verbs and verb phrases / clauses

nouns verbs

Teacher B

Now, when we have two objects A and B colliding. Of course, you will be given the mass of the objects, you will be given the initial velocity of the objects, you can calculate the kinetic energy for the objects. So you can calculate the kinetic energy before they've collided and you can calculate the sum thereof of the kinetic energies after they've collided. Now, two things can happen. If the energies are equal therefore this collision here it would be...an elastic collision. Ok, that is what we can get. Also, if the sum of the kinetic energies before they've collided is not equals to the kinetic energies after they've collided then we can get inelastic collision.

Lexical density: ratio of nouns to clauses (1.11)

21 nouns in 117 words

19 verbs and verb phrases

nouns verbs

Teacher A had a lexical density of 2.73 compared to Teacher B who had 1.11. Teacher A's lexical density was almost three times that of Teacher B's. This means that Teacher B had fewer content words making his speech easier to understand. He also had a higher number of verbs in his speech which implies less nominalisation. Previously it was mentioned that nominalisation tends to represent processes as things which can lead to learners coming to understandings that are not in line with the scientific view.

Learners will clearly struggling with the higher level of content words as they will have to work through many concepts that are all condensed in a single sentence. To highlight one of these incidents, I will relate an episode in Teacher A's classroom where he requested the definition of one of the laws of reflection from his learners. Below is an excerpt of the episode:

T: And the last one it says state the laws of reflection, state the two laws of reflection. Number 1? Number 1? The laws of reflection? [Sotho] The law of reflection Pippy?

L: The angle of incidence it's equal to the lawed of refraction incident ray ...

T: Awah, o kwala You are saying?

L: The angle of incidence is equals to the lord of reflection i ...

T: Wa reng[What are you saying?] *lots of*

L: Law inci ... the angle of incidence

T: State the law you are stating the law so how can you use the word law?

L: oh the reflected ray ...

It is very difficult to muster sympathy for Pippy's inability to state the law of reflection considering Teacher A covered the topic the previous day. In addition, she could access the information from her textbook as Teacher A provided his class with the page numbers where they could find the answers.

Teacher A eventually asked another learner to give the answer of which he gave a perfect delivery.

L: the angle of incidence is equal to the angle of reflection

T: Yes ne! E Kwala pele. [Write it correctly there].

From the perspective of the long noun sentences that typify the language of school science, it might have been very difficult for the learner to make meaning of all the words that Teacher A used in defining the law. He jumped from *incident* to *incidence*, from *reflection* to *reflected* without any pause to explain to learners why it was necessary for an *incident angle* to become an *angle of incidence*? The large number of these content words (*angle*, *incidence*, *equal*, *reflection*) in the statement of the law of reflection made the task linguistically even more difficult.

Learners who do not have exposure to the kind of discourse used in school take longer to digest information put to them in LSS. It is therefore advantageous to learners and the overall learning process if teachers gradually increase the number of content words they use in sentences. This, however, will require an unpacking and re-packing of some nominalised words so that learners can relate to them as they are in their verb or adjective form.

4.4 De Facto language practices in the science classroom

Research question 3 concerns itself with the practices employed by Teachers A and B to assist learners with the LoLT. From observations, the researcher has identified the practice of code switching which was unique to Teacher A's classroom. Although what was practiced by Teacher B was not unique to his classroom, the researcher observed comparatively more occurrences of learners doing calculations on their own or in groups for substantial periods of time in his classroom. These episodes can be seen as opportunities for learners to become familiar with the language of school science. In line with Lemke's 1990 assertion that learning science is learning to talk the language of science, what follows is an analysis of these practices and their implications for language learning.

4.4.1 Code switching

The practice where teachers use two languages to explain science concepts in a teaching situation is referred to as code switching (Setati et al., 2002). During the interview, Teacher A displayed a keen awareness of learners' struggles when LoLT happen to be English. He gave reasons for why learners needed to be taught science in their home language and for his use of code switching whilst teaching. Following is an excerpt of his opinion around home language teaching expressed during the interview.

> *R: Ok, Sir. I just wanted to ask on this on the mother tongue issue. Does the mother tongue really cater for them? Does it cater for explaining science?*
>
> *T: Yes, it caters a lot especially for those learners who can't read. We have learners in science who can't read at all.*
>
> *R: OK?*
>
> *T: so the background is that you have to start with the mother tongue.*
>
> *R: OK.*
>
> *T: … and explain clearly what is it that you are bringing across. Then, at the same time, step by step introduce that is the thing, or maybe the context or maybe the words that you need them to learn. So it does that its play a role.*

Teacher A's observed practice did not correspond to any of the strategies that he was professing in the interview. He did address his learners in Sepedi but very little of his vernacular use was aimed at aiding learners' understanding of science concepts or English words. He mostly used code switching to motivate/mock slow learners to work faster, for example, *o staraga* (you are slow). *Re etse practical ya rona* (we are going to do our practical), *Ro nna* (we are going to sit from …), *So le seke lambora* (don't bore me) and *Seka ntakatakantsa* (don't confuse me) are examples of the words and their translations that Teacher A used during his code switching. Table 11.1 (see Appendix 4) contains a complete list of the Sepedi words that Teacher A used during his teaching.

Possible opportunities to describe an *emergent ray* as "a ray coming out of" or explaining the meaning of the word *reflect* as "a bouncing of" were never taken. No attempts were either made to aid understanding by translating English science words into Sepedi. Table 4.11 below represents the categorisation of the Sepedi words, sentences or phrases used by Teacher A. The categorisation was adopted from Probyn (2015), and the findings are in line with the results of that study.

The least number of words in Teacher A's speech were used for constructing and transmitting science knowledge. More words served the purpose of classroom management and interpersonal relations and to humanise the classroom climate.

Table 4.11 *Function served by the Sepedi words in Teacher A's speech*

Function	**Percentage of words/phrases**
constructing and transmitting science knowledge	4%
classroom management	57%
interpersonal relations and to humanise the classroom climate	39%

Setati et al. (2002) envisaged a continuum from exploratory talk to discourse specific talk scaffolded by the teacher's code switching. As was the case in Setati's study, this outcome of code switching was not evident from Teacher A's use of the vernacular. Unlike in the Setati study where learners remained at the exploratory phase of talk, with the exception of a few, learners in Teacher A's classroom seldom spoke science to him be it in English or the vernacular. These learners generally had limited opportunities to develop their LSS considering that it is highly unlikely that they would use science discourse in other settings. Most of the science concepts used in the lesson were left to the learners' own interpretation whilst explanations of science concepts were predominantly in English. These EFALs were left to fend for themselves as far as learning science through the English language was concerned.

The above finding confirms Probyn's (2015) assertion that the teacher's classroom language needs to be examined more closely for the pedagogical value it has for learning science. One out of the eight teachers that she observed made use of the language resources of the learners' home language in a manner that benefitted overall science learning. Probyn (2015) proposes the term "pedagogical translanguaging" with a meaning distinct from code switching and translation in that "the notion of translanguaging reflects acceptance of a heteroglossic/bilingual reality and a more comprehensive and flexible use of the classroom language resources to mediate learning" (p. 222). The researcher therefore understands translanguaging as a realisation that the language of school science (LSS) differs from everyday language use and language resources from the learners' home language is incorporated primarily to communicate science. It is therefore no longer so much an argument as to which language to teach in but how that language is used to communicate LSS.

The attempt by a learner to make sense of the teaching on refraction is reported in the following excerpt:

> *L: Sir, o itse refraction ya occurra if e 90, if itlile perpendicular to the surface* (Sir, you said refraction is occurring if the light strikes at 90 degrees to the surface)
>
> *T: Ke matoma* (it is the first time I hear this!)

The teacher's response to the learner's assertion is seen as an indication of how valuable a two way communication in classroom interactions is and the high level of speculation involved in any claim that learners understand what teachers are saying.

The fact that Teacher A did not interrogate his code switching for its effectiveness in conveying the science concepts might be interpreted as a view that language is transparent. However, during an interview, Teacher A indicated that he was aware of the lack of a "technical language" in the vernacular as per the excerpt below:

> *R:… do you think that language is a big part of why learners are struggling or do you think that there are bigger issues at play here?*
>
> *T: … but in other nations, as I have noted, it's their mother tongue and, at the same time, it's a technical language in their mother tongue. It's made it easier.*

He also communicated a keen awareness about difficulties EFALs experience when being taught in English. This concern did not correspond to the little language support provided by Teacher A to his learners. Considering that this study earlier on reported that Teacher A's attempts to assist learners with vocabulary building was more in line with assisting learners with homophony rather than polysemy lead the researcher to conclude that Teacher A just did not know how to make the changes that LoLT undergo in order to convey science, explicit to his learners. In addition, it appeared as if Teacher A was experiencing the dilemma that Chval et al. (2014) identify whereby teachers might consider adapting content with the aim to make context more accessible to learners as compromising the standard of the science content taught. This confirms the assertion that teachers do not really know how to assist learners with their language needs in the science classroom (Wellington & Ireson, 2008). In the absence of explicit training to make teachers aware of the linguistic challenges of LSS, a focus on home language vs English merely re-enforces learners' experience of science as a foreign language. The little science knowledge conveyed by Teacher A during instances when he addressed learners in Sepedi was evidence to that.

Teacher A's approach to accommodating the learners' language deficiencies in the science classroom was mostly unsuccessful. This was in line with what Probyn (2015) reported that only one of the eight teachers managed to make use of isiXhosa in a manner that his language use contributed to the overall understanding of science concepts. Teachers should focus on conveying the science meaning when they use the vernacular to teach.

Teacher A also appeared well aware of the limitations of his learners' home language as is evident in the following excerpt.

> *T: Then also the challenge it is that normally you start with their language and with their language but some other time you find the challenge with the language that it does not expand. For example, when I talk of power in Pedi you say power ke matla, you say electricity, electricity also in African language it's still ke matla you say current let's say current it's still ke matla. So those are the challenges that we normally get but if you start them there to show them that our African language it's not giving this diversity of a word. At the same time, it grants me the opportunity to say that science is able to unpack one word where it says in Pedi ke matla but that matla could be meaning power, could be meaning electricity or could be meaning current. And in those three contexts you're able to explain the differences as you move that is along.*

Teacher A's assertion that the one word *ke matla* with its many meanings allows him to explain to learners the specificity of science meanings is in line with the concept of translanguaging yet the observed practise fell short of achieving this goal.

The researcher makes the assertion that the language of school science is out of focus in this particular EFALs science classroom because of the teacher's belief that the absence of home language teaching is the reason for learners' struggles in Physical Science.

4.4.2 English Home Language Learning – teaching the enacted curriculum

Geelan (2013) reported on 21 excellent teachers' practices during the explanation of physics concepts as observed during his study. This is how Geelan (2013) defines successful explanation:

> [the] teachers' ability to move between qualitative and quantitative modes of discussion, attention to what students require to succeed in high stakes examinations, thoughtful use of analogies, storytelling and references to the history of science, the use of educational technology, and the use of humor (p. 1751).

Teacher B's observed teaching practice was comparatively more in line with those of the teachers described in Geelan's (2013) study. Calculations almost always formed part of an explanation in Teacher B's classroom. The fact that learners would eventually have to prove their level of understanding in a test or an examination was never far from the minds of learners and teacher alike. This common goal was quite evident in the eagerness with which learners responded to opportunities to do calculations on their own or in groups. It should not be surprising that most of the activities described by Geelan (2013) and observed in Teacher B's classroom are achieved through the means of language since according to Halliday (1993) language can be regarded as the ontogenesis (origin) of learning.

The researcher will now report on Teacher B's classroom activities in relation to language practices embedded in those activities.

4.4.2.1 Providing opportunities to talk science

Teacher B created extensive opportunities for his learners to use language in the classroom environment. Learners tended to team up in groups when attempting science problems in the classrooms. The groups were seldom bigger than two learners per group. During these episodes, the classroom was abuzz with learner-learner discussion and the learners who preferred to work on their own called Teacher B to clarify or give direction whenever they felt they needed it. The undertone of competition amongst groups, implied that learners were not only listening to their own group discussion but also the science talk that were happening in other groups. During the group discussions, Teacher B visited each group or individual where he then did one-on-one teaching which provided the opportunity to correct learners' misconceptions.

Developing learners' understanding and skill in using LSS was not a focus during such interactions, as is evident from the excerpt below, as communicated by Teacher B to the researcher.

> *T: We now going to come to the force and the time. What is the real impact of impulse in everyday life? But before I do that* ***I just want to make sure that my calculations are fine****, they know how to do the calculations. So I've given them 25 minutes for this, I know it is 28 marks, just give them few minutes.*

Despite the clear focus on exam readiness, the researcher is of the opinion that learners in Teacher B's classroom were provided with ample opportunities to practice fluency in using the language of school science. It could be argued that the outcome of such interaction would have been more tangible if language learning was an explicit focus.

4.4.2.2 Effective modeling of the use of the language of school science

It was mentioned earlier in section 4.2.4 that it was difficult to fault Teacher B's vocabulary use in terms of its correctness. The same observation can be made about his delivery of LSS. However, Teacher B's language use was never motivated by his intention to enculturate learners in developing competency in LSS. He voiced the opinion that LSS offered equal challenges to both home and first additional language learners (EHLs and EFALs). He also saw challenges in LSS in terms of vocabulary only, which he felt that a teacher should be able to explain well enough to address those difficulties. The excerpt below serves as evidence to his views:

> *T: But previously I had taught at a school where we had first language and second language. But to be honest, really the difference is so little if ever is there.*
>
> *R: That's interesting.*
>
> *T: I have noticed that, for example, in a math class you know I mean when you are writing your x and y, really there is no other language.*
>
> *R: no substitute for x and y.*
>
> *T: Ja, so whether a person is first language or second, I think it is just the same. More also with science, yes there are some words but I mean we explain them and a person who has done second language should be able to understand so the difference is so little.*

It is ironic that Teacher B used an example that is renowned for learners' struggle to distinguish between a placeholder and variable function of an *x* or a *y* in algebraic expressions or equations (Ely & Adams, 2012).

A possible motivation for his language use could be in accordance with the following observation by Moje (1995, p. 351):

> the academic speech community may use language in ways that allow them to maintain their identity with that community. Consequently, students who strive to be successful in school will likely adopt the teacher's language patterns to become a part of the classroom community.

Two assertions can be made from Moje's statement, firstly that Teacher B considered his language use necessary to be considered part of the science community and his lack of focus on language during his teaching practice an indication that he considers the explanations that he provide about science concepts as sufficient to assist learners to do well in Physical Science assessments. The second assertion is that Teacher B's learners may benefit from his language use in that they may try to emulate it.

The researcher wishes to take issue with the second assertion. It is possible that some learners may develop understanding by adopting the teachers' manner of speech. However, given that language is not transparent, science concepts therefore cannot mediate meaning by themselves irrespective of the language used (Clark, 1997). Meaning is embedded in the language hence the onus is on the science teacher to facilitate that meaning through instruction of the salient features of LSS.

Teacher B's language use was well executed in that he did not make much use of grammatical metaphor or dense noun sentences, but his manner of speech did require learners to follow a long line of argument as the excerpt below indicates.

> *T: Guys, if you can think carefully you've got two objects here which are colliding. Now, the force which the first object is exerting on the other one is the same as the force by another object on that object. Also, the time of contact, if object A is in contact with object B for two seconds object B will be in contact with object A for two seconds as well, ok. So the value there would be 24000 Newton second west. That one is east that one is west. What is the* ***average change in momentum of the car****?*

Teacher B's own understanding of the language of school science allowed him to simplify his language use and in so doing had fewer occasions where learners had to grapple with complex language as well as science content. The oversimplification of language does have its drawbacks in that the teacher end up being the only one who is able to deal with complex sentence structures. Fang (2006) suggested a gradual increase in the complexity of sentences to assist learners in reading science. Although Teacher B displays a sophisticated command of the language of school science, the absence of any attempts to make his language choices explicit to learners has caused the researcher to conclude that the language modelling of Teacher B is mostly ineffective for the majority of learners in his classroom.

This conclusion was formed from his revelation that he found teaching Physical Science to be much easier when learners are in the top sets. During the interview, he mentioned that their school had a practice of streaming their learners in sets from 1 to 5 and the class that was observed was from the third set. The learners in the top sets could easily resemble the learners who according to Moje (1995) can successfully learn LSS by adopting the language patterns used by the teacher. The majority of learners however generally benefit more if the teacher consciously engages learners in the learning about LSS. Teachers B's response to learner difficulty is typical to that of many science teachers who ascribe learners' difficulty to understand science content as an indication that these learners might lack the aptitude to do science.

The researcher is of the opinion that the general experience of language as being opaque in the science classroom might explain why learners in classrooms of expert teachers, as the teachers reported in the Geelan (2013) study, still experience difficulty with understanding Physical Science.

4.4.2.3 Discussions about language

Reading science text provides an opportunity for learners to develop skills around LSS. The excerpt below demonstrates an episode where Teacher B had an opportunity to assist his learners to engage in the language of school science.

> *T: , … Lets' open on page 35. I want us to open on page 35 checkpoint 10. I'm waiting. Now, in checkpoint 10 we've got a golf ball, we are given its mass and we've got a golf club we are given its mass and the velocity before impact, before the collision. Now I want you to do this example. Find out if this collision is elastic or inelastic.*

Teacher B did not cease the opportunity to allow learners to read the question themselves. He interpreted the question on their behalf and requested them to do the sum. This is in line with his practice throughout the observation to simplify the science as much as possible for his learners. The learners missed an opportunity to derive science meaning from written text and to become familiar with how these science questions are asked. The researcher therefore concludes that discussions about language was not a focus in the science classroom.

4.5 Summary

In this chapter, language use in the classroom was considered from a word level and a language level. Words used as science concepts were generally explained by both teachers. Little attention was given to words that were used in science context.

Although the teaching of the salient aspects of LSS was generally not paramount in both teachers' teaching approaches, language, being an integral part of any learning process in school, permeated everything that they were doing. This led to a consideration of teachers' de facto language practices in teaching science.

Code switching as a means to assist EFALs in the classroom where the LoLT is predominantly English, need to fulfil the dual role of learning science and language. In the absence of this approach, learners will still experience language as a barrier to learning science because of the different meanings everyday language communicate when used to do science.

Telling can only aid understanding to a point. It is therefore important that teachers inform learners of their language choices and the meaning that a specific choice will convey. Opportunities for learners to engage with the language through written text should be a teaching strategy. The next chapter will discuss the findings in relation to the research questions.

5 Chapter 5

Discussion

5.1 Introduction

This chapter will highlight the findings of Chapter 4 and discuss them in relation to the research questions posed in Chapter 3.

5.2 Research Question 1

> Given the polysemous nature of words, is there evidence of Physical Science teachers' awareness of the potential for confusion that the technical and non-technical words in a science context pose in the science classroom?

In asking this research question, the researcher wanted to establish if the two teachers valued word understanding in a science classroom. The everyday English words that were used as *science concepts* or non-technical words in a *science context*, were under scrutiny as they are familiar words that assume unfamiliar meanings. Most words used by the two science teachers were unexplained hence learners could come to understandings that were not necessarily intended by the teacher. The teachers generally assumed that the intended meaning was communicated by the contexts of the science teaching. Devices that teachers employed like the equations or diagrams to define a science concept posed their own difficulties to learners hence, in the opinion of the researcher, could not guarantee that learners would understand the intended meaning. No formal vocabulary instruction was therefore observed.

Both teachers demonstrated an unawareness of the importance of vocabulary building whilst teaching. However, Teacher B demonstrated a sophisticated understanding of the different meanings that words assume in different contexts when this question was explored during an interview. This finding caused the researcher to conclude that an unawareness of the polysemous nature of words may manifest on at least the following two distinct levels. Firstly, a teacher might be intent on using the correct vocabulary as Moje (1995) posits, simply to maintain their identity with the particular speech community. Such motivation does not inform their learners on the meaning that they can derive from words.

The second level of unawareness is the omission to focus on vocabulary building due to the teacher's own shortcomings. The teachers themselves might be unaware that learners are unable to discover changed meanings of English words when used in a science context or as a science word. The changed meaning due to the new context might not be explained to the learners and they may remain oblivious to the fact that their understanding of words may not be in line with that of the science community. From Lave and Wenger's (1991) perspective of communities of practice, it is highly unlikely that all learners would understand science language without explicit intervention through vocabulary teaching by the teacher or knowledgeable other. Both scenarios therefore prove detrimental to learners' overall understanding of science.

From their study Carlisle, Flemming, and Gudbrandsen (2000) conclude that significant incidental word learning occurs during oral instructions. Incidental word learning refers to the acquisition of word meaning by inferring meaning from discourse or graphical displays. It is therefore probable that learners in Teacher A and B's respective classrooms might acquire some understanding of words used as *science concepts* as this type of words were normally accompanied by an explanation. However, Carlisle et al. (2000) found that meaningful improvement of concept word knowledge was only evident for learners who already had partial understanding of words. The rest prove to have an only partial understanding of concept words at the end of a unit taught if incidental learning was the only means through which they had to obtain word knowledge. Teacher B's skilful use of the science vocabulary is therefore a valuable resource in the science classroom, but it is a resource that is not equally accessible to all learners. It is also very probable that the learners in Teacher A's classroom, given their challenges with LoLT, may resemble learners in the Carlisle et al. (2000) study who could not demonstrate a significant understanding of concept words after the unit was completed.

Knowledge of English words used as science words (words in *science context*) which Carlisle et al. (2000) call non-topical words was reported not to improve during an incidental focus on vocabulary instruction. This has implications for this study where the observation was that most of the English words that were used as science words were left unexplained in the two science classrooms. These are words that EHLs might have encountered outside the classroom and they may have an advantage over their EFALs counterparts who might never have come across those words. Considering the link that Haug and Ødegaard (2014) made between conceptual knowledge and highly developed word knowledge this could in part explain why grade 12 Physical Science results are still racially skewed.

Learners' natural response in situations where they are faced with incomprehensible knowledge is to commit this information to memory or follow rote learning. Below is how a learner dealt with a conclusion in class that *impulse* is equal to the change in momentum after long discussions in which they failed to see this point:

> *Sir, can you go as far as then always say that impulse is the change in momentum?*

The drawback of such an approach is that the learners are seldom able to perform well because of the limited understanding of or exposure to a concept. The focus on assessing understanding of science words in the current examinations are through multiple choice questions of definitions. The nature of these questions does not discriminate between understanding and memorisation since the current demands are mostly an ability to recall. The detractors that are part of the multiple choice questions are easily distinguishable from the correct answer if the learner has memorised definitions verbatim.

5.3 Research question 2

> Do teachers consciously endeavour to teach towards establishing a common understanding amongst learners and the science community?

The second research question considered teachers' conscious teaching of the linguistic resources that make up the language of school science.

5.3.1 Language as a semiotic system

In her study C. Jacobs (2007) provided the following quote from one of the lecturers she interviewed:

> '. . . the notion of the discourse is that when you're inside one and you've been inside one for a long time, you forget what it's like to be outside of it. You don't actually know, it's like so much part of you that it's hard to step outside of it. As soon as you move into the field of one's own discipline, the rules of the discourse take over; it's not a sort of conscious thing. It's actually quite unconscious. You're simply doing it . . ..'(p. 873)

The interviewee stated that being a teacher of a discipline for many years makes it difficult to "see" the language although it might be quite opaque to the novice. The observation is that this was the experience for learners in the two classes observed. The teachers were very clear on the equation (Snells' law, impulse momentum theory) that they wanted to derive and in order to achieve that they "read 'through' the genres and discourses to get to the meaning" C. Jacobs (2007, p. 874). This overt focus on meaning and the treatment of language as transparent is not in line with a SFL perspective as asserted by Halliday (1993, p. 93)

> "Language development is learning how to mean".

Teachers' attempts to explain science knowledge to learners are therefore in most cases hindered by an omission to explain the semiotic nature of language.

5.3.2 Nominalisation and Dense noun sentences

Teacher A's ineffective use of LoLT to construe LSS caused him to emphasise the learning of definitions without much support to learners on how to deal with the nominalisations locked up in those definitions. He realised that the sentence structure of those definitions were in itself problematic to learners' understanding due to the embedded complex terms. However, it seemed as if he considered this as a difficulty that came with the LSS when the LoLT is English. This might point to a need for a realisation from teachers' side that they are not necessarily presenting work that is conceptually less challenging to learners if they adapt content with the aim to make context more accessible to learners (Chval et al., 2014). Fang (2006) posits that exposure to LSS is an essential part of becoming science literate but also cautions that it does not guarantee mastery. An important additional element is the understanding of the grammar of the language of school science. The absence of any explicit attempts to engage learners in the manner in which LoLT construe science meaning in Teacher A's classroom practise is confirmation of the assertion by Wellington and Osborne (2001) that teachers generally do not know how to teach language in the science classroom.

Gibbons (2003) used a construct which she called mode continuum to describe the approach of assisting learners to master the language of school science (LSS). She suggested that teachers should vary the mode from informal everyday speech to speech that is equivalent to formal writing, whilst assisting learners to learn LSS as well as the content. Teacher A's approach to leave most of his nominalisations and abstractions unpacked posed a difficulty for learners. This was quite aptly illustrated in section 4.3.3 when Pippy was asked to state the laws of reflection.

Teacher B's language use was much simpler in that he mostly unpacked norminalised words. This practice, considering the mode continuum construct (Gibbons, 2003), could facilitate the explorative stages of engagement with science concepts. However, Martin (2013) asserts that if this is the teacher's language use throughout, as a result of this practice "…students were continually stranded in common sense, with lessons progressing by skipping from one fragment of knowledge to another instead of by building knowledge" (p.33). This was the observation that the researcher made about the learners in Teacher B's classroom. They displayed fragmented understanding of science concepts and struggled to make links between concepts from one lesson to another.

The language practices of the two teachers represented two parts of what Maton (2013) called a semantic wave. This is "where knowledge is transformed between relatively decontextualized, condensed meanings and context-dependent, simplified meanings" (p. 8). On the one side of knowledge building is what Maton (2013) calls strengthening semantic density. That is when the teacher moves from relatively simple meanings to more complex meanings representing the ebb of a wave and weakening semantic density moving from more to less complex meaning representing the flow of a wave. Martin (2013) refers to this as "unpacking of unfamiliar technicality and abstraction and re- packing it orally as notes on the board to consolidate it in preparation for writing – strengthening semantic density as the unit unfolds …" (p. 33). The researcher is in agreement with Martin (2013) who asserts that successful modeling of LSS requires that teachers engage in weakening and strengthening of semantic density during their teaching. Teacher A's language practice only represents the semantic strengthening leaving his learners to struggle with unpacking the meaning from those complex structures. Teachers B, on the other hand, did all the unpacking on behalf of the learners, as a result, they seemed unable to form conceptual links.

5.4 Research question 3

> Do teachers provide a pedagogy that scaffolds language learning and learning through language?

The third research question aimed to establish whether teachers combined a focus on the language of learning and teaching (LoLT) with teaching the language of school science (LSS) in order to assist learners with the learning of Physical Science.

5.4.1 Assisting English First Additional Language Learners (EFALs)

The South African context where many learners are taught in a language other than their home language makes it imperative that teachers afford opportunities to learners and EFALs, in particular, to learn the language of instruction (LoLT) whilst learning the content. It is however also important to caution that the approach cannot be one where the focus is purely on developing proficiency. Carrejo and Reinhartz (2012, p. 37) conclude that there is a “continuum of learning between science and language and teachers do not have to make a choice as to which one to focus on”. C. Jacobs (2007) similarly calls for an integrated approach that acknowledges that language plays an important role in how disciplines structure their knowledge bases and produce text. Lee and Fradd (1998) sum this up as saying that when learners are not from the dominant society, it is on the teacher to make the culture’s rules explicit and visible. Research conducted abroad on EFALs learning science, have identified a positive correlation between improved outcomes and interventions that are “equally focussed on student communication skills and conceptual understanding” (Ardasheva, Norton-Meier, & Hand, 2015, p. 211). In light of the above, the researcher asserts that should code switching be used as a tool to minimise the foreignness of the LoLT, it should still facilitate an understanding of science concepts.

Code switching aimed at taking advantage of bi- or multilingualism can be a useful tool as it “helps the learner to see different representations of the same ideas” (Rollnick, 2000, p. 100). In the same study Rollnick commented on the observation that she made about an episode reported in Martin’s study (Martin (1999) as cited in Rollnick, 2000, p. 103). The teacher translated all words and phrases but the phrase 'carbohydrates give us energy' which Rollnick considered conceptually most challenging was left untranslated. This highlights the limitations inherent in an approach to code switching that is a mere translation from one language to another.

It is for this reason that the challenge of learning science goes beyond proficiency (Oyoo, 2007) in that the language of science is not transparent and science concepts cannot mediate meaning by themselves irrespective of language (Clark, 1997). The teacher needs to understand the language demands of LSS and adapt the LoLT in such a manner that the LoLT addresses those demands. Chval et al. (2014) suggest that teachers should connect language with its mathematical representation while Fang (2006) considers it beneficial if learners are encouraged to translate everyday language into the LSS and vice versa.

Professional development in how to assist EFALs is also an overlooked area in teacher training. Chval et al. (2014, p. 12) identified the following additional practices that they regard as important in a classroom where the aim is to build learners knowledge “about language and through language”:

- creating a classroom environment that values learners' contributions
- talking about language should be as important as talking about the content
- content area teachers should familiarise themselves with language teaching techniques

Recent studies by Probyn (2015) and the observation made in this study indicate that teachers are still not all able to use home language as a resource to assist learners with understanding science concepts in the science classroom where teaching predominantly happens in English.

5.4.2 Assisting English Home Language Learners (EHLs)

Whereas the language focus for EFALs classroom erroneously appears to be on their proficiency or lack thereof in LoLT, the focus for EHLs classrooms appears to be on the symbolic representation of LoLT used in the science classroom. It therefore becomes clear that EHLs will experience the same difficulty whereby they might become stuck in an everyday understanding of science words unable to extract the science meaning if left unassisted. Lemke (1990) posits that teachers very often merely use meaning relationships and seldom explain them to learners. Opportunities to learn science can therefore be measured by the frequency of occurrences where learners engage with how to talk science, how to put sentences together and write science text. The absence of these opportunities has a less severe effect on learners with a background that uses language closer to the manner in which science is construed but severely disadvantage their peers that come from a less similar environment. LoLT is a tool that can be used very effectively in a EHLs classroom as most learners will be comfortable speaking in their home language. When looking at learner performance comparatively teachers are sometimes tempted to ascribe underperformance to a lack of aptitude whereas it could very well simply be a case of language patterns that are less familiar to some learners. Omitting to explicitly teach learners how LSS employs LoLT to convey science meaning can result in opposing thematic patterns (Lemke 1990) that leave learners unable to come to a scientific understanding.

5.5 Summary

In this Chapter, it was argued that both EFALs and EHLs need to be enculturated in the LSS. An awareness amongst teachers of the polysemous nature of words can encourage vocabulary building not only for technical terms but also ordinary English words that have assumed status of science words. Teachers should also display an awareness of the challenges that LSS offer to science learners. Caution not to treat language as transparent but to continuously find ways to develop learners' competency to use and apply LSS to do science is important. Teachers therefore need to provide opportunities for learners to become familiar with how and what LSS means as communicated through LoLT. This might at times mean that teachers have to move to a more familiar context in order to make science meaning clear. Assisting EFALs to become proficient with LoLT cannot be done separate from understanding how LoLT changes to communicate science. It is this transformation of ordinary English into LSS that causes EHLs to equally struggle in the science classroom. Understanding how language is embedded in classroom practices provides a basis to engage in language teaching even in a science classroom where learners are predominantly English speaking.

The next Chapter will summarise the implications for learning and teaching when language learning is kept out of focus during teaching of science concepts. Shortcomings of this study and suggestions for future research on the topic of teacher classroom language will also be discussed next.

6 Chapter 6

Conclusion

Learning is in many ways a linguistic process, and the construal of non-everyday meanings in non-congruent grammar involves thinking in ways that ***are*** *the content of school subjects and academic disciplines* (Schleppegrell, 2004, emphasis in original).

6.1 Implications for teaching and learning school science

Science teaching that generally keeps language out of focus has the potential to leave the learner unaware of the meanings that the teacher conveys during the teaching episode. Learners generally benefit more if the teacher consciously use language in an appropriate manner. This resonates with Mohan and Slater (2006) who make a case for teachers to focus on conveying both relevant language skills and content instruction when teaching science. This is a practice that can benefit both EFALs and EHLs.

Clerk and Rutherford (2000) concluded that their study indicated that learners' difficulty with the language of school science (LSS) might masquerade as misconceptions. They highlighted that remedial actions might be unsuccessful if the real cause for a learner's difficulty with subject matter cannot be identified. They also called for a greater focus on language in teaching science.

Both teachers intuitively corrected the incorrect use of science words or terms but none had an explicit focus on language teaching. This highlighted the importance of learner participation since although language may not be a focus of Physical Science teaching, most teachers will know if it is used correctly. Correct use of LSS implies a better understanding of the science concepts as learners then do not simply repeat what was said before, but they can construct sentences to convey an intended meaning. Learning language and learning through language calls for teachers to understand that science requires an *engagement with the language* that is used to convey its meaning. Learners need to be able to understand the language of science that is presented in the manner in which the grammar is structured. The majority of learner may not be able to come to a science understanding without a teacher's intervention to assist learners to understand how the grammar is structured to construe meaning.

It is unfortunate to report that, considering the practices of Teachers A and B, language is still very much out of focus in those two science classroom. The opportunities that learners were afforded to do science and develop a science vocabulary through incidental word learning, was significantly higher in Teacher B's classroom. This was due to the fact that he assisted learners with unpacking nominalisations and dense noun sentences by using much simpler language. Self-driven learners in Teacher B's classroom had some of the tools at their disposal to develop science understanding and to perform well in high stakes examinations.

However if the aim is to eventually contribute to the building of a science literate society, than a bigger focus on the language of school science is warranted. Science teachers need to become aware that teaching science requires a dual role, that of teachers of language as well as teachers of science. This will allow science teachers to become aware of the many modalities that LSS uses to communicate meaning.

6.2 Shortcomings of the research

The data were collected using video recordings of the teachers' observed lessons. The focus of this research was on the language use of the teacher but many interactions in Teacher B's classroom were between teacher and learners and, since the learners did not have any cameras or recorders near them, it was not always possible to follow the teacher when he spoke to individual learners. The focus on the teachers' talk only was unfortunate in the sense that learner responses were good indications of how effective the teachers' language use was. Both teachers observed were males which made it difficult to conclude whether female teachers would further lean towards language learning and learning through language.

This study would have delivered deeper insight into teacher language use if it was done in collaboration with linguists. The lack of linguistic expertise hampered the depth of the study even though helpful articles and books on the topic of systemic functional linguistics made it possible to complete the study. The fact that more scientists are linking science understanding with proficiency in LSS is very encouraging.

The absence of a research team forced the researcher to make unilateral decisions to categorise words as explained or not. The validity of the findings would have been stronger if the opinion of a second person could have been solicited. However, by listing the text that accompanied the word, the reader is in a position to verify the researcher's claim. Despite these hindrances, insight gained from this study will stimulate debate and corroboration between linguist and scientist.

Given the fact that this was a case study it was never the intention to generalise the findings in this study as representative of the typical South African Physical Science teacher. Having worked with two very different teachers introduced factors that made it very difficult to comparatively voice opinions of the two teachers' language practices in the science classroom. The scope of this study does not allow evidence to make a selection between the practices of the two teachers and might be explored in further studies. It is however informative that LSS was generally out of focus in both science classrooms.

6.3 Suggestions for future research

The researcher envisages a future study that will consider a larger sample of high school teachers. Future studies around teacher awareness of language use in the classroom should be structured in such a manner that learners' responses are audible in such a study. Head cameras to see learners' work will also greatly enhance the quality of data that one can obtain from classroom observations. Given the evidence of the lack of focus on language teaching in the science classroom, it will also be beneficial to examine teachers' responses in the classroom after there have been interventions to equip teachers with the skills to analyse the language demands in the classroom. Collaboration between linguists and scientists is imperative to attain the deep knowledge that such a study can unearth.

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8 Appendix 1: Ethics Clearance

Wits School of Education

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25 February 2015

Student Number: 9411416D

Protocol Number: 2015ECE004M

Dear Regina White

Application for Ethics Clearance: Master of Education

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has considered your application for ethics clearance for your proposal entitled:

Polysemy and context in the science classroom language: teacher classroom language for understanding science

The committee recently met and I am pleased to inform you that clearance was granted. However, there were a few small issues which the committee would appreciate you attending to before embarking on your research.

The following comments were made:

- The invitation letters should include rationale for videotaping as per section 2.4 (a brief sentence to the principal and participants should suffice). Under 5.1. you should include video taping.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

Wits School of Education

011 717-3416

Cc Supervisor: Dr Emmanuel Mushayikwa

9 Appendix 2: Observation Schedule

Table 9.1 *Observation schedule*

Categorising Language use	**Description**	**Guiding questions**
Specialist language presented	teacher explains words and forms of language unique to the subject that has the potential to obscure understanding.	• Is teacher spending time on vocabulary building highlighting polysemy? • Is teacher making learners aware of the salient meanings that the language of science construe? • Are there examples of opportunities where teacher explained words and form?
Specialist language not presented	teacher does not explain words and forms of language unique to the subject that has the potential to obscure understanding.	• Is teacher spending time on vocabulary building highlighting polysemy? • Is teacher making learners aware of the salient meaning that the language of science construe? • Are there examples of opportunities where teacher could have explained words and form?
Language of secondary education	Teacher uses terms, words and forms of language that the learner would not necessarily encounter except in the world of school.	• Does teacher use metacognitive and metalinguistic terms during teaching science? • Does teacher emphasise the difference in meaning of concepts when they use the language of the science classroom and everyday language use.

10 Appendix 3: Interview Schedule

Table 10.1 *Broad concepts addressed during interview*

Broad concept	**Sample question**
Awareness of Polysemy and context	• Do you think that learners sometimes carry words from their everyday speech into the classroom unaware that the meaning might be different in the classroom? • How do you ensure that you and your learners share the same meaning for a word used in your lesson?
Second language learners	• I have noticed that you do have learners in your classroom whose first language is not necessarily English. Does that influence your teaching approach at all?
Everyday meaning vs science meaning of concepts	• Do you find yourself teaching concepts where the learner's experience of the natural world interferes with conceptualisation? • How do you use language to "convince" your learners of the correctness of the science view
Language of science classroom	• Research claims that learning science is akin to learning a second language hence learners must be provided with opportunities to talk science. How do you provide learners with this opportunity?

11 Appendix 4: List of Sepedi words used by Teacher A

Table 11.1 *Sepedi words used by Teacher A*

Sepedi	English translation
The refractive index there, *ke bo kae* ?	It is how much
Le tlo ya beyang?	How are you going to get there
Nplakise Ke feditse Lefeditse go ngwala, ke emitse lona lengwala	Plug…. Are you done writing I am waiting for you to finish writing
Tse three tse ko go filleng tsona Ko page 320	
Re tlo ngwala ko mafelong	we are going to write at the end
Bula……O seke wa ba close thata	Open, don't be too close
Gona Ko morago gona moo	At the back there just there
O ka nkeletsa calculation o etsa gona ya nong ke go file question	You are going to do the calculation, you are doing it now, I gave you the question
He, ko dimo	Pardon, at the top
Ele yona seka na gana go re kelebetse exercise ya page 223	Don't think I forgot about that exercise On page 223
Learner: Sir, o *itse* refraction *ya occurra* if *e* 90, if *itlile* perpendicular to the surface Teacher: Ke matoma!!!	Learner: Sir, you said refraction is occurring if the light strikes at 90 degrees to the surface Teacher: it is the first time I hear this!!!
Le tlo ntirela	You are going to do for me

Ke mang oleng absent kajeko? O kare gona le motho oleng absent ke mang??……. He, ke wena?	Who is absent today? It seems that someone is absent, who is it Pardon, is it you?
O feditse? Tshwantse ke le betele di buka	Are you done? I it seems I should start hitting you for your books
ka dilo tse three	with the following three things
steal it *le wena* e teng ka mo Bibilenge ga e yo e	steal it back It is there in the Bible is'nt it?, yes
Ke mang o itseng o utswe	who said you should steal?
He, Bibile wena o reng?	Pardon, the Bible, what are you saying about it?
Ke Jesu o boletseng.beyalo	it is Jesus who said that
A ke moruti, ke moruti wa lentswe A ke moruti	I am not a pastor I am a shepherd of the word
Seun, mara wena o tshanetse go nna mo pele	Seun but you are suppose to sit in front
Ke ya mang ruler e	Whose ruler is this?
So le seke lambora	don't bore me
o staraga	you are slow