

**Exploring Intersemiotic Complementarity in three Namibian Physical
Science teachers' classroom practice**

A thesis submitted in fulfilment of the requirements for the degree

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By

Tomas Nakakuwa

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DECLARATION

I, Tomas Nakakuwa, hereby declare that this thesis is my own original work and has not been previously submitted in any form for assessment or for a degree in any other higher education institution. All ideas, quotations and other materials used in this study derived from the work of other people have been acknowledged using complete references according to Rhodes University Education Department Guidelines.

Signature: 

Date: 31 January 2019

DEDICATION

This thesis is dedicated to the following people:

My late father, Tobias Nakakuwa

My late aunty, Johanna Mhata

My mom, Veronika Mhata

My son, Joshua Lihongeni Nakakuwa

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ABSTRACT

The Namibian Science curriculum promotes learners' development of self-confidence, self-knowledge and understanding of the world in which they live. The world we live in is increasingly multimodal, necessitating a multiliteracy in learners in order for them to engage meaningfully with knowledge and skills. Furthermore, scientists themselves engage in a range of inscription practices. While verbal language is the primary medium through which scientific knowledge and concepts are constructed, communicated, and learned, visuals can help learners to gain knowledge that they may not receive from verbal explanation alone. The verbal and visual semiotic modes can also function in a complementarity way, and this is significant in contexts where science lessons are for the most part in a second language - as is the case in Namibia where the language of learning and teaching (LoLT) of English is commonly not the learners' mother tongue.

However, no studies were found exploring the nature of verbal-visual intersemiotic complementarity in the practice of Namibian science teachers, or whether it was related to the number of years of science teaching experience. This study thus aimed to explore the dynamics of verbal-visual intersemiotic complementarity in the classroom practice of three Junior Secondary Physical Science teachers, with varying amounts of science teaching experience, in the Oshana region of Namibia. This qualitative case study, on the dynamics of verbal-visual intersemiotic complementarity in science teacher classroom practice follows in the path of earlier studies which employed Systemic Functional Linguistics (SFL) in the analysis of multimodal discourse. This thesis is also informed by Social Constructivism in which the various semiotic modes are recognised as components of the toolkit for mediating learning. The study adopted the interpretive paradigm. Data collection involved lesson observations and semi-structured interviews. Data analysis involved identification and coding of themes and categories inductively.

The results reveal that the participant teachers employed the full range of intersemiotic sense relations which literature outlines. It was found that the ideational meanings in the verbal and visual modes of the science teachers' practice are lexico-semantically related through these intersemiotic sense relations. While some teachers utilised some intersemiotic sense relations

more often than others, there were no correspondences evident between the use of verbal-visual intersemiotic complementarity and the number of years of science teaching experience. The results also indicated that different intersemiotic sense relations served different purposes in the science classroom. The verbal-visual intersemiotic complementarity in the participant teachers' practice tended to focus on: physical material, processes, symbolism or resemblance.

This study has significant implications, providing an empirical basis for informing pre-service Physical Science teachers' training and guiding the in-service training of Physical Science teachers in Namibia. Since its effective use may not be left up to teaching experience, Namibian Physical Science teacher training programmes need to include the use of verbal-visual intersemiotic complementarity in order to equip and empower Physical Science teachers.

Key Words:

Semiotic modes, multimodal science discourse, Intersemiotic Complementarity, Social Constructivism, Systemic Functional Linguistics.

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LIST OF ABBREVIATIONS AND ACRONYMS

MoE	Ministry of Education
MoEAC	Ministry of Education, Arts and Culture
MBEAC	Ministry of Basic Education, Arts and Culture
SFL	Systemic Functional Linguistics
No	Number
T1 – 3	Teacher 1 to 3
IT1 – 3	Interviewed Teacher 1 to 3
ICT	Information and Communication Technologies

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CHAPTER ONE: INTRODUCTION

1.1. Introduction

The purpose of this study was to explore the verbal-visual intersemiotic complementarity in the classroom practice of three Namibian Physical Science teachers with varying amounts of science teaching experience. In this Chapter, I introduce the study by presenting the background, and giving an overview of the language context of Namibian teachers and learners. I also looked at Physical Science in the Namibian curriculum. I then provide statement of the research problem. Thereafter, I indicate the research goal and questions, and highlight the significance of this study. An overview of the thesis' Chapters is then provided, before the chapter summary.

1.2. Background of the study

It is important to undertake a review of the overall terrain being researched in a study, in order to provide an overview of the research and set the scene for a thesis (Opoku & Ahmed, 2016). This can be achieved by considering the current literature relevant to the issue, previous studies related to it and historical context. In this section, I thus show consideration of the performance of learners in science subjects, the Examiners' reports for Namibian Junior Secondary Certificate (JSC) Physical Science, as well as factors contributing to poor performance. I also describe the semiotic modes of communication, the semiotic modes in relation to the science classroom, and the verbal mode as a challenge to Namibian learners. I then look at the effect of teachers' experiences on learners' learning before I specify the focus of the study.

1.2.1. Performance of learners in science

One of the overall problems in school education is the general poor performance of many learners in science subjects globally (Ryan, 2009). More than two decades ago, Lewin (1993) revealed that the majority of learners who do not do well in science, are based in developing

countries. From the previous years' results, Namibia is no exception to the worrisome trend of poor by school science learners. The performance of learners in Namibia is gauged by the Grade 10 and Grade 12 national examination results. In Namibia, a learner's mark from an 'A' symbol through to an 'E' symbol is considered a pass, but in ranking of regions and schools the percentage of A-C are commonly used. The national and regional (Oshana region) results for 2015 – 2017 for Grade 10 Physical Science are presented in the Table 1.

Table 1: Namibia national results and Oshana region results for Grade 10 Physical Science (Namibia. MoEAC, 2015 – 2017).

Year	2015	2016	2017
A-C symbols Nationally	28.3%	31.2%	30.0%
A-C symbols in Oshana Region	41.6%	44.5%	41.9%

While the Oshana region average is consistently higher than the national average, the region is one of the less performing regions in Namibia. Although the table shows some improvement in the Oshana regions results from 2015 to 2016, the results decreased from 2016 to 2017. Furthermore, the region failed to reach its target of 70% for the years 2015 – 2017. Other northern regions such as Oshikoto have been performing better than Oshana. The average number of A-C symbols for Oshikoto was 49.5% in 2015, 47.4% in 2016, and 52% in 2017.

1.2.2. Examiners' Reports for Namibian Junior Secondary Certificate Physical Science

Overall commentary of learners' performance and associated reasons are provided in the annual examiners' reports. According to the 2015 Grade 10 Physical Science Examiners' Report, most students showed little or no understanding of most Physical Science concepts (Namibia. MoEAC, 2015). In 2016, the Examiners' Report indicated that learners' answers for questions covering several topics showed that they lacked scientific knowledge and many were unable to express deep understanding when answering questions (Namibia. MoEAC, 2016).

Although the Physical Science syllabus in Namibia aims at producing learners who are scientifically literate, evidence suggests that that was not achieved at Junior Secondary phase. The Examiners' Reports from previous years indicated that learners were unable to demonstrate understanding of scientific concepts when answering some questions (Namibia. MoEAC, 2017). The 2017 Examiners' Report also expressed concern with learners' inability to demonstrate an understanding of what the questions required (Namibia. MoEAC, 2017). In 2016, the Examiners' Report expressed concern with a large number of learners that were unable to interpret statistical information presented in graphs. This issue is also stated in the 2017 Examiners' Report. Furthermore, learners struggled to relate the periodic table in the question paper (a version with some information missing) to the complete periodic table provided at the end of the question paper for them to refer to (Namibia. MoEAC, 2016). These examples show the need to explore the dynamics of verbal-visual intersemiotic complementarity in Namibian Physical Science classroom pedagogy.

1.2.3. Some factors contributing to poor performance

There are various possible contributing factors to learners' poor performance. A survey carried out by the European Commission (2007) revealed that one of the contributing factors to poor performance is that in most countries, classroom teaching and learning of science often involved learners simply memorising information instead of investigating and understanding concepts. It is also argued that some schools, specifically those in developing countries, provide low quality education to the learners due to their failure to prepare and use visuals in their classrooms (Kaswa, 2015). Ankomah, Koomson, Bosu, and Oduro (2005) point out teachers' personal characteristics as another factor that has an effect on learners' academic achievement. "The personal characteristics include academic qualifications, pedagogical training, content training, aptitude, and years of service/experience" (Kimani, Kara & Njagi, 2013, p. 4). The multimodal discourse of science is also another possible contributing factor to poor performance in science subjects (Ryu, 2015; Zhang, 2008). The process of conceptualising and communicating science ideas requires teachers to use different methods to mediate learners' sense making (Bennett, 2011). In science classrooms, teachers use figures, graphs,

diagrams, and mathematical equations when communicating scientific ideas to learners. Bennett (2011) reminds us that all of these methods of representing ideas and concepts in science classroom involve different modes of representation. “Science learners need to become enculturated into these same forms of communication” (Bennett, 2011, p. 33). Learners are required to be fluent in them if they are to be successful in the science classroom and beyond (Lemke, 2000).

1.2.4. Semiotic modes

We are living in a world of signs. There are visual signs – like text, paintings, photographs, sculptures and animations. There are also verbal signs, which are “the subject of modern linguistic science” (Royce, 1999, p. 1). Signs operate to serve different purposes in our everyday lives. They guide, protect, inform and warn. Signs that are used as resources for making meaning are referred to as semiotic modes (Kress & van Leeuwen, 2001). Semiotic modes can occur in isolation or in combination. For example, verbal and visual modes are used in Christmas cards, in ballet, as well as in opera (Royce, 1999). In science classrooms, the verbal mode and the visual mode are used by teachers to communicate science meanings. For example, a teacher can use a picture of the periodic table of elements in combination with the verbal mode to explain how elements are arranged in the period table according to certain properties. In the examples given above, the semiotic modes of communication complement each other to communicate a meaning and that relation is called *intersemiotic complementarity*. The term intersemiotic itself means the circulation of meaning between different sign systems, for example, when the image includes reference to the verbal, and the verbal referring to the image (Aktulum, 2017).

1.2.5. Semiotic modes in science classroom

Teachers have a range of communicative modes available for them to use – for example, verbal mode, gesture mode, visual mode, and written text mode. Among these communicative modes, Márquez, Izquierdo and Espinet (2006) state that teachers often use visual and written text modes on the chalkboard during science lessons, while Ryu and Boggs (2016) indicate that the

verbal and visual modes are the two semiotic modes that teachers often use in their teaching. Waldrup, Prain and Carolan (2006) reveal that most learners face significant challenges in engaging effectively with different semiotic modes. Also, in recent years there has been a shift from a monomodal view of communication, which refers to the use of a single semiotic mode, to a multimodal view (Márquez et al., 2006), which is based on the interactions of different semiotic modes. While the verbal mode and visual mode might not depend on each other, they have a potential to offer more if they are combined (Royce, 2007).

Science classroom communication itself is widely accepted as multimodal nowadays (Márquez et al., 2006). Due to the multimodality of science, learning science in school requires learners to understand and link different semiotic modes for them to develop knowledge of scientific concepts and processes (Lemke, 2000). Waldrup et al. (2006) add that if the use of different semiotic modes in science classrooms is incorporated, learners' individual learning needs, preferences, and interests are likely to be addressed. That has the potential to support learners' development of scientific literacy. The use of different modes in classrooms helps learners to make sense of what they are learning (Kress, Ogborn and Martins, 1998). For example, the visual mode can help learners to obtain knowledge that they may otherwise not get from the verbal explanation alone (Patrick, Carter & Wiebe, 2005). Different semiotic modes also work together systematically (Royce, 1998) and this has implications for Physical Science teachers' use of the verbal and visual modes in their classrooms. Due to the multimodal nature of science discourse (Márquez et al., 2006), learners' challenges with semiotic modes are problematic for science education.

Although there is an increase in the use of different semiotic modes in everyday activities, the combined use of different semiotic modes (multimodality) in classrooms is not growing at the same pace. There has however been some improvement in recent years due to the increased use of new technologies in preparing and presenting scientific activities in the science classroom and beyond (Waldrup et al., 2006). The use of visual modes in printed materials, projectors and video presentations can be observed across Namibian schools, mostly in urban areas (Isaacs, 2007). The use of these different semiotic modes to conduct and represent scientific activity in the science classroom poses challenges to science teachers' development and effective use of classroom teaching and learning strategies (Waldrup et al., 2006). There is

a need for teachers to develop multimodal thinking and reasoning in teaching contexts that are consistent with current general principles of effective pedagogy for science learning (Waldrup et al., 2006).

1.2.6. The verbal mode as a challenge to Namibian learners

Royce (2007) argues that the verbal mode is the dominant semiotic mode, this is also true in Namibian science classrooms (Murray, 2007). The visual mode is commonly used as subordinate to the verbal mode (Royce, 2007). The verbal mode being the most used mode of communication in Namibian classrooms, is problematic. This is due to the fact that most Namibian learners are English Second Language (ESL) speakers while English is the only language of learning and teaching (LoLT) in the country in secondary schooling. The Namibia language policy indicates that English should be the only LoLT from Grade 5, for learners to be proficiency enough in the nation's official language (Namibia. Ministry of Education [MoE], 1992). According to the language policy, this will help learners to get access to further education, because English is used widely around the world (Namibia. MoBESC, 2003).

It is problematic that the majority of ESL learners have English as the LoLT and yet encounter English for the first time at school (Wolfaardt, 2005). Also, when science is taught in English, ESL speakers may not be able to apply what they learned in science into everyday life (Bunyi, 1999). Furthermore, Namibian learners may find it difficult to learn Physical Science, since meanings are developed through language (Fang, 2004; Scott, 1998). Controlled use of the verbal mode, and matching the pedagogy and the use of verbal mode allows teachers to facilitate and promote active involvement of learners in their learning (Walsh, 2002). Besides that, Arroio and de Souza (2012) remind us that the construction of meaning occurs not just through the verbal mode, but also through gestures, animations, diagrams and mathematical symbols.

1.2.7. The effects of teachers' years of teaching experience on learners' learning

Zhang (2008) suggests that it is possible for teachers who have more years of teaching experience in a certain science subject to have a greater impact on learners' achievements in that subject than those who do not. Rice (2010) agrees that more experienced teachers are often more effective in their teaching, than teachers with little or no experience. A number of scholars (for example, Carter et al., 1988; Rink et al., 1994; Hogan et al., 2003) also argue that years of teachers' teaching experience influence cognition and representation. Through teaching experience, teachers gain pedagogical knowledge that they can use to organise information into meaningful units (Wolff, et al. 2016). In their study, Harris and Sass (2011) reveal that the impact of years of teachers' teaching experience in teaching Mathematics and Science subjects is stronger at the Senior Primary phase and the Junior Secondary phase than at senior secondary phase.

1.2.8. The focus of the study

The poor performance in Physical Science in Namibian schools discussed in the previous sections needs to be addressed. As discussed earlier, multimodal discourse in teaching has the potential to improve learners' academic performance since science itself is multimodal. However, no study was found which explores how Namibian science teachers employ the verbal and visual modes in their pedagogic practice. It was also discussed earlier that the number of years of science teaching experience might influence the ability of teachers to integrate different semiotic modes, but this was not investigated in the Namibian science education context.

1.3. Language context of Namibian teachers and learners

Before independence, Namibia had been linguistically and politically isolated (Simasiku, Kasanda & Smit, 2015). Afrikaans, which is not an international language, was used as lingua franca in most Namibian schools (Namibia. Ministry of Basic Education, Sports and Culture [MBESC], 1999). At independence in 1990, the new government chose English as the

country's official language. The new administration found it necessary to introduce English as the official language and the medium of instruction in schools since it is the language of wider communication (compared to Afrikaans), and it was believed to unite the Namibian people (Brock-Utne & Holmarsdottir, 2001). The country had no history of English as a colonial language, and only minority citizens spoke it as their first language. However, the decision was regarded as important because it was expected to open many doors to Namibian students. It would increase the opportunities of Namibians to further their studies at different universities worldwide, compared to Afrikaans which only spoken in Namibia and South Africa.

Namibia's English only language policy has implications on learning and teaching ability. The majority of Namibian children have to learn through a language in which they are neither competent nor feel comfortable with. In some Namibian schools neither learners nor teachers feel proficient and comfortable in the language used as medium of instruction (Swarts, 2002). Simasiku, Kasanda and Smit (2015) indicate that both Namibian teachers and learners are not conversant enough to teach and learn school subjects through English as a medium of instruction.

As with other African countries, Namibia is faced with problems of unqualified or under-qualified teachers. Two decades ago, Peacock (1995) reported that teachers were poorly qualified in terms of content and their command of the English language. More recently, in 2011, a staggering 22 089 out of 23 000 Namibian teachers failed the English Language Proficiency Test (ELPT), which was organised by the Ministry of Education in collaboration with the University of Namibia (Kisting, 2011). That is problematic since those teachers are expected to teach in English, a language in which they are not competent.

Many learners in African rural schools are only exposed to English at school (Ferreira, 2011). Namibia is no exception. English is not encountered in the immediate environment of many learners attending Namibian rural schools (Marsh, Ontero & Shikongo, 2002). Like other African countries, in Namibia the situation is better in urban schools, where learners have greater access to English through magazines, newspapers and television (Setati et al, 2002). In

some towns, learners also have access to a larger number of English language speakers in their environment.

ESL learners are faced with a double challenge when English is used as LoLT in science classrooms. Rollnick (2000) reminds us that learners who are learning science through a second language are engaging in two social practices at the same time. They are required to learn English language and the scientific language simultaneously.

1.4. Physical Science in the Namibian curriculum

One of the aims of the Namibia Basic Education Curriculum is to enable learners to think scientifically and apply scientific knowledge in different aspects of life (Namibia. Ministry of Education [MoE], 2009). For the country to produce the much-needed scientists, the Natural Sciences syllabus aims to provide basic scientific background to learners (Namibia. MoEAC, 2015). Physical Science is one of the Natural Science subjects in the Namibian curriculum. The subject is offered from Grade 8 up to Grade 12. The aims of the Namibian curriculum which are promoted by Physical Science includes, knowledge with understanding, values and attitudes, scientific skills and democratic principles (Namibia. MoEAC, 2015).

At the Junior Secondary phase, Physical Science emphasises learners' understanding of the physical and biological world around them at local, national and international levels (Namibia. MoEAC, 2015). The subject content includes how societies use natural resources in their environment to satisfy their needs, and how the environment may be changed in ecologically sustainable ways (Namibia. MoEAC, 2015). At Junior Secondary phase, Physical Science emphasis that the application of scientific knowledge and attitudes to health is relevant for the individual, the family and society as a whole (Namibia. MoEAC, 2015).

The approach to teaching and learning of Physical Science in Namibia is based on a paradigm of learner-centred education (LCE) (Namibia. MoEAC, 2015), which is described in

ministerial policy documents and the learner-centred education conceptual framework (Namibia. Ministry of Basic Education [MoBE], 2003). LCE is a learning model where learners are placed at the centre of the learning process. Learners influence the content, activities, materials and pace of learning (Collins & O'Brien, 2003). The approach aims to ensure that Namibian learners bring to school the knowledge and experience gained when they engage with family, the community and through interaction with their environment (Namibia. MoE, 2009). Furthermore, the Physical Science syllabus acknowledges that some learners might not be able to achieve all the specific objectives satisfactorily. Those learners need to receive learning support through adapted teaching approaches, materials, and assistance from peers and more knowledgeable others (MKO) (Namibia. MoEAC, 2015).

Namibia subscribes to the notion of 'English across the curriculum' (Namibia. MoE, 2008). English across the curriculum is widely considered to be the backbone of curricula in schools (Nazir, Chen, Gardner, Wong & Chan, 2016). According to the Physical Science Subject Policy in Namibia, the notion aims to ensure that in every subject there are activities designed to improve learners' skills in English reading, writing and spelling (Namibia. MoE, 2008). The fact that English is the only official language and the medium of instruction from grade 5 upwards in Namibia, makes English play a special role in the Namibian schools. The National Curriculum for Basic Education states that "all teachers have the responsibility to improve the learners' aural/oral skills in discussion, reflection and reporting; their perceptual skills in using different types of reading techniques and materials; and their written skills especially in summaries, note taking, writing papers and reports" (Namibia. MoE, 2009, p. 27).

The curriculum further highlights that it is the responsibility of all teachers to identify where the learners have limited English language skills, in order to provide the best opportunities for learners to practice them (Namibia. MoE, 2009). All teachers in Namibia, irrespective of the subject that they teach, are required to develop the learners' core skill of communication (Namibia. MoE, 2009). In the case of science, the curriculum demands science teachers to facilitate the development of learners' familiarity with and ease in using, the terminology of science and its discourse. As discussed earlier, English is a second language for the majority of Namibian learners, the curriculum calls for subject teachers to take time to ensure that

learners understand the vocabulary, technical terms and jargon of the subject, not as abstract terms to be learnt by rote, but to be able to use them correctly and meaningfully in context (Namibia. MoE, 2009).

1.5. Statement of research problem

Considering the multimodality of science discourse, teachers' ability to work across semiotic modes (e.g. the verbal mode and the visual mode) is critical for communication of scientific knowledge and mediating learners' acquisition of scientific knowledge. Different teachers may employ various semiotic modes for teaching Physical Science differently, depending on such things as their level of experience in teaching (Ryu, 2015). As mentioned earlier, teachers commonly use the verbal and visual modes in science classroom discourse. This makes it challenging to ESL learners (Senom, Zakaria & Shah, 2013), due to the idea that language mediates thought (Vygotsky, 1987). Learners are expected to learn through the LoLT in which they are not competent. Although Halliday stressed that "language is a meaning-making system" (Royce, 1998, p. 26), he acknowledges that there are many modes for meaning-making other than language (Halliday & Hasan, 1984). In addition, O'Halloran (2011) reminds us of the abovementioned point regarding science discourse being multimodal.

Royce (2007) highlights that while much work has been done on verbal language in classroom communication, as well as on the importance of the visual mode in classrooms, little work has been done on the actual nature of how the verbal mode and the visual mode can be combined to work together to communicate meaning and mediate learning. The knowledge gap around verbal-visual intersemiotic complementarity of science teachers' pedagogic practice, coupled with potential benefits of decreasing that gap, provides a strong rationale for exploration of the nature of Namibian science teachers' use of the verbal and visual modes in their classroom pedagogic practice. Based on Halliday's (1978) views of language as a social semiotic resource, this research extends linguistic analytical approaches to uncover the intersemiotic complementarity of the verbal and visual modes in multimodal science discourse. Since the language aspect of this study is focused on spoken utterances rather than written texts, the term *verbal mode* is used instead of *language*.

1.6. Research goal

The goal of this study is to explore verbal-visual intersemiotic complementarity in the pedagogic practice of three Junior Secondary Physical Science teachers across a range of years of teaching experience in Namibia.

1.7. Research questions

1.7.1. Main question

What is the nature of the verbal-visual intersemiotic complementarity of Physical Science teachers' classroom pedagogic practice in Namibia?

1.7.2. Sub questions

1. How do the Namibian Physical Science teachers use verbal-visual intersemiotic complementarity in their lessons?
2. What are the correspondences (if any) between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience?

1.8. Significance of the study

Learners' low performance in science subjects, and the multimodality of science classroom discourse calls for changes in science teachers' classroom practise. Some teachers' inability to coordinate semiotic modes across each other in science classrooms highlights a significant gap in teacher training. The situation can be improved if teachers provide a framework for creative learning through ensuring productive interaction and enhancing communication through appropriate selection and combination of modes (Marchetti, 2016). In cases like that of the Namibian situation, where most learners are learning in a second language, Marchetti (2016)

argues that appropriate selection and combination of modes can offer a springboard to satisfy cognitive differences, as well as to achieve individual and general aims and objectives.

Lesson observations and semi-structured interviews are undertaken in this study for answering the research questions. Research question 1 focuses on how the Namibian Physical Science teachers use verbal-visual intersemiotic complementarity in their lessons. Research question 2 focuses on possible correspondences between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience. Findings related to the two research questions provide an empirical basis for shaping pre-service science teacher training and guiding in-service science teacher training in Namibia.

1.9. Overview of the thesis' Chapters

This thesis is divided into six Chapters. Chapter one introduces the study by detailing the background, the rationale, the significance of the study, the research goal and the research questions. Chapter two presents a review of the literature on: semiotic modes, multimodal discourse in science classrooms, language as a semiotic mode in science classrooms, the visual semiotic mode in science classrooms, and intersemiotic complementarity. Chapter three provides a description of Social Constructivism Theory, the theoretical framework informing this study, and Systemic Functional Linguistics (SFL) Theory, the analytical framework for the study. Chapter four details the research methodology of this study including issues relating to ethics, validity and trustworthiness. Chapter five includes the presentation and discussion of the findings. Chapter six contains the conclusion drawn from the study, its limitations, and some recommendations stemming from the findings.

1.10. Chapter summary

In this Chapter, I introduced the study by presenting the background, the overview of the language context of Namibian teachers and learners. I also presented the statement of the research problem, the research goal, the research questions, the significance of the study and the outline of the thesis' Chapters. Chapter 2 presents the literature review for this study.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This Chapter presents a review of some literature relevant to this study. A literature review is a summary of key sources organised in certain patterns and synthesised within specific conceptual categories (Fink, 2013). Bertram and Christiansen (2014) note that the literature review shows how a study is related to others, by discussing important studies done in the field being researched. In this Chapter, I firstly discuss the concept of semiotic modes. Secondly, I discuss some studies on multimodal discourse in science classrooms. I then focus on verbal (language) as a semiotic mode in science classroom, as well as visual as a semiotic mode in science classroom, before ending the Chapter with a focus on intersemiotic complementarity.

2.2. Semiotic modes

Ferdinand de Saussure (1857-1913) and Charles Sanders Peirce (1839-1914) are regarded as the co-founders of semiotics. They established two major theoretical traditions: semiology by Saussure, and semiotics by Peirce. Saussure's term 'semiology' is sometimes referred to as the 'Saussurean tradition', while the term 'semiotics' is sometimes referred to as the 'Peircean tradition' (Eco, 1976). However, nowadays the term 'semiotics' is widely used as an umbrella term to embrace the whole field (Nöth, 1990).

Chandler (2007) defined semiotics as the study of signs. About a decade later, Kisak (2016) defined it as the study of meaning-making and the significance of signs and symbols in communications. Eco's (1976) definition of semiotics is broader - it states that "semiotics is concerned with everything that can be taken as a sign" (p. 7). A sign is defined by Saussure as a form made up of a signifier and a signified (Sebeok, 2001). A signifier is something physical (e.g. letters and gestures), while a signified is the image or concept to which the signifier refers. Chandler (2007) suggests that anything can be a sign as long as someone interprets it to stand for something apart from itself. That is supported earlier by Peirce (1931, p. 172) who notes that "nothing is a sign unless it is interpreted as a sign". From arts and photography, signs can be

drawings, paintings and photographs, while from language, signs include words and sounds (Chandler, 2007).

Semioticians are concerned with how human beings represent their world to themselves and to others (Yakin & Totu, 2014). They study how meanings are made and how reality is represented through signs (Eco, 1976). This reveals that semioticians do not study signs in isolation, but as part of semiotic sign-systems (Adebola, 2017). The main principle of semiotics is that meaning is made by the disposition of acts and objects which function as signs in relation to other signs (Mehawesh, 2014). Mehawesh explains that “the complex meaning relations that can exist between one sign and another constitutes the system of signs” (Mehawesh, 2014, p. 87). The relations include repetition, synonyms, antonyms, hyponyms, meronyms and co-location (discussed further in Chapters 3 and 4). Semiotics is often associated with linguistics, but Kisak (2016) reminds us that semiotics also studies non-linguistic sign systems. Based on semioticians, signs take the form of words, images, sounds, gestures and objects.

Different systems for meaning-making such as speech, writing and image are known as semiotic modes. Semiotic modes include visuals, verbal, written, gestural and musical resources for communication (Yu & Yan, 2013). O’Halloran (2011) argues that semiotic modes include language and other resources, such as images, scientific symbolism, gesture, action, music and sound. Kress and van Leeuwen (2001) claim that folk costume, poetry, traffic signs, classical music, fashion, and theatre are also semiotic modes. Semiotic modes also include various ‘multimodal’ ensembles of any of these modes (Kress & van Leeuwen, 2001). Chandler (2007) notes that some media draw on several semiotic modes: television and films, for example, utilize verbal, visuals, auditory and locomotive signs. Newspapers and magazines utilize texts and visuals. Science education is not confined to specific semiotic modes because teachers can also use television, newspapers and magazines as teaching and learning resources in classrooms.

Baldry and Thibault (2006) claim that the term ‘semiotic resources’ refers to the possible forms used to make meaning in particular contexts. O’Halloran (2011) adds that the term is used to describe the modes (e.g. language, image, music, gesture and architecture) which integrate

across sensory modalities (e.g. visuals, auditory, tactile, olfactory, gustatory and kinaesthetic) in multimodal discourse. Although semiotic resources are often linked to the use of the term ‘semiotic modes’, O’Halloran, Tan, Smith and Podlasov (2010) argue that semiotic resources are categorised based on their functions within a particular context.

Halliday (1978) introduced the term ‘social semiotics’. Social semiotics focuses on all types of social meaning-making practices, whether visual mode, verbal mode or aural mode (Thibault, 1991). Being interested in language, Halliday proposes that language and society cannot be separated. Language is one of the semiotic systems where culture is created and maintained (Halliday, 1978). He suggests that the way people interact must be viewed in their social context. It is significant to note that since language and society are amalgamated, they should be studied as a whole. Mehawesh (2014) agrees that language should be interpreted within a sociocultural context, in which the culture itself is interpreted.

2.3. Multimodal discourse in Science classrooms

As mentioned in section 2.2, the term ‘multimodal’ is used to express the use of more than one semiotic mode. There is nothing revolutionary about multimodality if one considers that communication has always involved the use of different modes (Marchetti & Cullen, 2016). What has been changing is the general communication in society at large (Marchetti & Cullen, 2016). According to Marchetti and Cullen (2016), the origin of the term *multimodality* was established in a seminal article by the New London Group (1996). The New London Group (1996) discussed how changes in communication, as influenced by new technologies, urgently needed to be addressed regarding teaching and learning through different semiotic modes. The notion of *multimodal discourse* was first proposed by Jewitt and Kress (2003), who explained it as the understanding of different ways of knowledge representation and meaning-making.

Lim and Tan (2017) note that a multimodal approach focuses on how linguistic and visual (or other semiotic mode) choices fulfil the purpose of a text, the audience and context, and how the chosen semiotic modes work together to organise and develop information and ideas. Marchetti and Cullen (2016) alert us to the fact that a multimodal approach can enhance the

classroom experience by improving interaction between teachers and learners, and classroom communication in general.

Lemke (1998) introduced the term *semiotic hybrid* to express the idea that scientific concepts are presented simultaneously using verbal, visual, mathematical, and actional modes. Furthermore, Jewitt, Kress, Ogborn and Tsatsarelis (2001) suggest that learning is realised through the interaction between visual, actional and linguistic communication (verbal) modes, and involves the transformation of information across different communicative systems – e.g. from verbal mode to visual mode. For Márquez et al. (2006), each of the semiotic modes can be considered as a channel of communication that provides equivalent, complementary, redundant, or contradictory information. Márquez and colleagues add that it is the interaction between different modes that makes the construction of meaning possible.

Multimodal discourse is important in a science classroom, more especially in the current world, where the influence of internet technology on the teaching and learning processes is higher (Waldrip et al., 2006). Science teachers need to design and use different interactive semiotic modes as teaching and learning tools in multimodal science classrooms. Considering multimodality of science discourse and the increased use of technology, Waldrip et al. (2006) propose that science teachers and educators of science teachers have to fully understand the possibilities and the limitations of using different semiotic resources in the 21st century. Computer mediated technologies like the ‘hypertext’ are some of the resources that teachers can search for, retrieve, and store scientific knowledge in across several semiotic modes and media in a matter of seconds (Livingstone, 2012).

Science discourse is multimodal in the sense that when science teachers speak, they mostly simultaneously use other semiotic resources (e.g. visual mode) for meaning-making (Márquez et al., 2006). That reminds us that science content is elaborated and negotiated through various semiotic resources (Axelsson, Danielsson, Jakobson & Uddling 2017). The use of different semiotic modes plays a significant role in teaching and learning of scientific concepts. Each mode contributes in a specific way (Kress, 2001), and different communicative modes have specific functions (Kress, Ogborn & Martins, 1998). The role that semiotic modes play in a

science classroom depends on the scientific concept taught and the phase in which teaching and learning is taking place (Márquez et al., 2006). It is the duty of teachers to choose the most effective communicative modes. Teachers also have the responsibility of deciding which modes they can integrate to communicate a meaning that cannot be communicated by a single mode alone.

2.4. Verbal language as a semiotic mode in science classrooms

Language is a semiotic resource, “it is an aspect of the study of meaning” (Halliday, 1985, p. 4). Language is the most important, the most comprehensive, and all-embracing semiotic mode (Halliday, 1985). Language has been dealt with fairly extensively in the past decades compared to other semiotic modes (Kress & van Leeuwen, 1996). Earlier, Barthes (1967) even goes as far as saying that every communication system has its linguistic admixture, and meanings of other semiotic modes are confirmed by being duplicated in a linguistic message. Furthermore, the assumption, which Kress, Ogborn and Martins (1998) described as implicit but potent, is that all significant activities in the classroom are expressed through language, mostly through talking. Kress, Ogborn and Martins (1998) agree that language is one of semiotic modes (communicational/representational) in use in any act of communication, but they argue that language may not be the central mode, since there is a number of other semiotic modes also available for communication purposes. Kress, Ogborn and Martins (1998) believe that there can be a specialisation of communicational and representational functions of the different modes. Representational function focusses on the engagement of the semiotic mode with the world and how meaning is realised by using that semiotic mode, and communicational function focusses on how to make the representational available to others by interacting with them (Bezemer & Kress, 2008).

According to Royce (2007), Halliday makes four central claims about language. The first claim is that language is *functional* in terms of what it can do or what can be done with it. The second claim is that language is *semantic*, meaning it is used to make meanings. The third claim is that language is *contextual*, meaning that meanings exchanged are influenced by their social and cultural situations. A number of scholars (e.g. Vygotsky, 1978; Whorf, 1956) also recognise the

cultural specificity of language. Language is a production of a given culture and the way that language is used is greatly determined by the culture that conditions its linguistic system (Oyama, 1998). The last claim is that language is *semiotic*, a process of making meanings by selecting from the set of options of what can be meant.

Halliday (1978) identified three metafunctions: The *Ideational metafunction*, the *Interpersonal metafunction* and the *Textual metafunction*. These are “kinds of meaning that are embodied in human language as a whole, forming the basis of the semantic organization of all-natural languages” (Halliday, 1985, p. 53). Metafunctions operate simultaneously in the semantics of every language (Royce, 2007) and are discussed further in Chapter Three.

Science discourse can be described as linguistically dense (Lemke, 1998). It has a high degree of abstraction (Axelsson, Danielsson, Jakobson & Uddling 2017), thus requiring teachers to handle multiple resources for communicating scientific knowledge to learners. The high degree of the abstract of science discourse can be challenging for learners, and even more distant from the lives of learners who are learning science in their second language (Axelsson, Danielsson, Jakobson & Uddling, 2017).

Verbal communication between a teacher and learners influences the classroom environment and quality of the instructional program (Webster & Johnson, 1987). This tells us that the ways in which science teachers use language for facilitating learners’ construction of knowledge and mediating learning in science classrooms is important. When it comes to language, science teachers should consider its appropriateness, its feasibility and correct ways of using it in a given situation (Hymes, 1974). Walsh (2002) reveals that some teachers, whether intentionally or not, often create opportunities for learners’ involvement in classroom communication through their use of language. In other words, teachers’ approach towards disciplinary discourse can either facilitate or constrain learners’ content area language use. Furthermore, Johnson (1995, p. 9) argues that “teachers can control what goes on in classrooms primarily through the ways in which they use language”, since the language that a teacher uses influences the ability of learners to understand. Thus, Scott (1998) proposes that teachers need to organise presentations of scientific knowledge in a way that it is understandable to all learners. Teachers

who share the same language and culture with learners, are more likely to provide teaching which is appropriate for learners' needs (Fradd & Lee, 1999). In the Oshana region of Namibia, that is likely to happen more in rural schools where most teachers and learners speak the same language (Oshiwambo). Urban schools are often multilingual and multicultural, making it more complex for teachers to help learners to achieve their academic goals.

Although language is seen as a complete medium of communication, Kress, Ogborn and Martins (1998) argue that it is far from being the only mode of communication in science classrooms. As discussed in previous sections, language is accompanied in science classrooms by visuals, gestures, mathematical symbols, animations, science apparatus, and other semiotic resources (Kress, Ogborn & Martins, 1998). In science classrooms, the verbal mode has the function of providing commentary on other modes (Kress & van Leeuwen, 2001).

2.5. Visuals as a semiotic mode in science classrooms

According to Curtin (2009), semiotician Roland Barthes (1915-1980) was the first to apply ideas of semiotics to visuals. Barthes (1977) argues that the meanings we attribute to the visuals are not a 'natural' result of what we see, but are attributed to how we understand what we see. This suggests that the visual mode is not self-evident and universal.

In everyday life environments such as, work, communication media, social activities and personal hobbies, people produce texts using the visual mode (such as visual instructions) in order to exchange information with others (Oyama, 1998). A number of studies (e.g. Cook, 2006; Lowe, 2000) reveal that there is an increase in the use of the visual mode in science education. The increased use of visual mode in science education is due to the integration of visual representations in the curriculum, because of the availability of computers and other technology resources (Stokes, 2002). Considering the increasing use of the visual mode and other semiotic modes such as gesture, sound and music (Cook, 1992), both the verbal mode and the visual mode need to be considered in a more systematic way (Oyama, 1998) when communicating scientific knowledge.

Although the use of visuals as a mode of communication has long been popular in communication media, in education contexts its eminence has grown in recent years (Royce, 1999). Several studies revealed that the visual mode plays a vital role in science education. Cook (2006) maintains that visual representations are effective in the communication of scientific concepts in classrooms. Waldrup et al. (2006) report that students' individual learning needs and interests can in fact be addressed if visual representations are used towards them acquiring literacy in science. Furthermore, the visual mode provides alternative ways of representing information and helping learners to obtain knowledge that they may not get from the verbal mode alone (Mayer, Bove, Bryman, Mars & Tapangco, 1996). Apart from their ability to attract attention and maintain motivation, visuals are also important in making visible 'phenomenon' that are too small (e.g. an atom), too large (e.g. a planet) or too fast (e.g. electric current) to see with the naked eye (Cook, 2006).

Considering the increase of visual communication and the overwhelming evidence of the importance of visual resources in scientific areas, Kress and van Leeuwen (1996) want the forms of communication employing visual mode to be treated as seriously as linguistic forms have been. Kress and van Leeuwen (1996) believe that, the visual mode being crucial in domains of public communication, will lead to new and additional rules regarding its use. They also believe that a person not being visually literate, will attract social sanctions.

Pozzer-Ardenghi and Roth (2005) suggest that when discussing visual representation in science teaching and learning, we need to consider both the way they are designed and the way they are interpreted by learners. Some visuals are unnecessarily demanding, cognitively. Visual representations should be designed in such a way that they reduce cognitive load, because learners have a limited working memory (Cook, 2006). The amount of years of teaching experience of teachers may influence their ability to design the visual mode that is pitched effectively at the learners' cognitive level. More experienced teachers are more likely able to coordinate features within and across different modes towards developing an understanding of concepts (Cook, 2006).

Curtin (2009) understands that the meaning of the visual mode does not only involve the visual mode and the individual, but is the result of complex inter-relationships between the individual, the visual mode and other factors such as culture and society. In contrast to the ideas of the influence of a culture on the use of the visual mode, Oyama (1998) argues that visuals can operate as a mode of communication regardless of a given culture and “without any problems that are caused by cultural difference” (Oyama, 1998, p. 25). The visual mode is a culturally transparent medium of communication (Oyama, 1998). In other words, people can interpret visual information regardless of cultural differences. However, the prior knowledge of learners needs to be considered. Cook (2006) expresses that individual differences, like prior knowledge, are critical in determining the effectiveness of a visual representation on learners’ cognitive structures and processes. Furthermore, it is argued that the visual mode facilitates the integration of new knowledge with prior knowledge (Roth, Bowen, & McGinn, 1999). Although prior knowledge seems to be the most influential factor on the effectiveness of visual design, Cook (2006) suggests that specific characteristics, such as spatial ability, cognitive ability, and developmental level, are the important determinants to be considered when designing the visual mode.

While visual modes are considered advantageous in science classrooms, Mayer (2001) warns that there is also a risk for visual modes being an impediment to learning. If the visual mode is not properly designed and difference among learners are not considered, the visual mode may be no better than verbal information alone or may even contribute negatively to learning, which can lead to misconceptions about scientific phenomena (Cook, 2006).

2.6. Intersemiotic complementarity

Intersemiotic Complementarity is derived from Halliday’s metafunctional view of communication as outlined by Systemic Functional Linguistics (SFL). It refers to instances when semiotic modes of communication complement each other to communicate a meaning or idea that cannot be communicated better by just one mode (Royce, 2007). It is used to explore meaning-making across different semiotic modes in multimodal texts in terms of Halliday’s ideational, interpersonal and textual metafunctions (Liu & O’Halloran, 2009). Intersemiotic complementarity is realised through various linguistic and visual means (Royce, 2007). Royce

(1998) used the term intersemiotic complementarity to explore the co-occurrence of the verbal and visual modes in a page-based multimodal text.

The term is also used by Kress and van Leeuwen (1990, 1996). For example, Kress and van Leeuwen (1990) used the term intersemiotic complementarity to describe the various ways by which the verbal and visual modes communicate meaning in graphic design, media studies, and visual semiotics, to develop a grammar of images which describes a variety of different kinds of meanings and the ways by which verbal-visual integration can realise them. Although Kress and van Leeuwen (1996) suggest that both the verbal and visual modes of communication can realise the same systems of meaning independently and via their own specific forms, they also acknowledge that the verbal and visual modes can also co-occur to communicate a coherent multimodal discourse through semantic devices which realise intersemiotic complementarity. As indicated earlier, Royce (1998, p. 26) reveals that “visual and verbal modes semantically complement each other to produce a single textual phenomenon”. In this study, the term intersemiotic complementarity is used to describe the relationship between the verbal and visual modes drawing from the definition by Royce (2007).

According to Cook (2006), the burden placed on learners’ working memory can be reduced by either increasing its capacity or reducing its cognitive load. Intersemiotic Complementarity of the verbal mode and the visual mode reduces unnecessary cognitive load by increasing the working memory capacity (Kirschner, 2002). The working memory of a human being has two components that processes verbal and visual information independently (Cook, 2006). If information is processed by two independent working memories, information can be managed through it being divided across the two systems (Cook, 2006). Thus, instructional presentations that contain both the verbal and visual modes are more beneficial than presentations that have verbal mode or visual mode alone (Mayer, 2001).

Drawing from the SFL, Royce (1998) outlined conditions that may lead to Intersemiotic Complementarity being achieved. First, the *Ideational* meanings in both modes (the verbal mode and the visual mode) have to be related lexicosemantically. Lexicosemantics is also known as lexical semantics. *Lexical* items/units are words or phrases, while *semantics* refers to

meaning (Fillmore, 2003). Thus, Lexicosemantics can be defined as the study of word meanings and their relationships (Partee, 1995). Baldwin and Bond (2003) define it as the study of what individual lexical items mean, why they mean what they do, how we can represent all of this, and where the combined interpretation for an utterance comes from. Second, the *Interpersonal* meanings have to be related. Lastly, the *Textual meanings* have to be integrated.

Each of the three metafunctions is about a different aspect of the world (Ye, 2010). The ideational metafunction is about content function of semiotic modes (Halliday, 2007). The interpersonal metafunction is about the social world, especially the relationship between speaker and hearer (Halliday, 2007). The textual metafunction is about the verbal world. It is realised in information structure and cohesion (Bilal, 2012). This study did not involve learners, and it did not concentrate on how the verbal mode and the visual mode are structured in multimodal science classroom discourse. Thus, the study did not use interpersonal and textual meanings to analyse the intersemiotic complementarity of the verbal and visual modes. The ideational metafunctional meanings which is used by this study to analyse the intersemiotic complementarity of the verbal and visual modes is defined and discussed further in Chapter's 3 and 4.

To create effective instructional material involving multiple modes, requires a deep understanding of what makes instruction effective in communicating scientific concepts (Hand, McDermott & Prain, 2015). In countries like Australia and the United Kingdom, the school curriculum involves support documents as appendices to the syllabi. This allows the curriculum to include detailed technical accounts of information to facilitate teachers' explicit use of intersemiotic complementarity (Unsworth, 2006).

Liu and O'Halloran (2009) highlight that previous research on image and text relations (e.g. Cheong, 2014; Lim 2004) overlooked the fact that the verbal mode and the visual mode are semantically integrated in multimodal discourse. Earlier research (e.g. Kress et al., 2001; O'Toole, 1994) reveals the possibility of the verbal mode and visual mode semantical integrations because all communication realises ideational, interpersonal and textual metafunctions. Royce (2007) proposes that both the verbal and visual modes of communication

complement each other in the ways that they communicate meaning. In Royce's earlier study on exploring intersemiotic complementarity in page-based multimodal text, the verbal and visual modes complemented each other semantically to produce a single textual phenomenon (Royce, 1998). Royce (1999) suggests that the verbal and visual modes have the ability to work together to produce a coherent multimodal discourse for learners in science classrooms.

The relationship between the verbal mode and the visual mode in multimodal discourse can be described as *verbal extending image*, or as *visuals extending text* (Unsworth, 2006). That means science teachers can use the verbal mode to extend the meanings from visual mode, and the visual mode to extend meanings from the verbal mode. Liu and O'Halloran (2009) argue that this kind of classification can be challenging as it is sometimes difficult to determine which mode of the message initiates and which follows.

2.7. Chapter summary

This chapter began with a discussion of the concept of semiotic mode, starting with the definition of semiotics, which a number of authors refer to as the study of signs. It also outlined different meaning-making systems – semiotic modes, such as the visual mode, the verbal mode, the written mode, the gestural mode, and the music mode. The Chapter also discussed terms related to semiotic modes such as, semiotic resources – forms used to make meaning in particular contexts (Baldry & Thibault, 2006), and social semiotics – all types of social meaning-making practices (Thibault, 1991). The multimodality of science classroom discourse, starting with multimodal discourse – different ways of knowledge representation and meaning-making (Jewitt & Kress, 2003). It was pointed out in this Chapter that science discourse is currently regarded as multimodal. When teaching, science teachers tend to simultaneously use different semiotic resources. This Chapter further looked at verbal (language), as well as visuals as semiotic modes in science classrooms. Starting with verbal language, the most important and the most comprehensive semiotic mode (Halliday, 1985). It was stated in this Chapter that all significant activities in the classroom are expressed through talk (language), necessitating the need for teachers to organise presentations of scientific knowledge in a way that it is understandable to all learners. On the other hand, it was argued

that in everyday life people use visual mode in order to exchange information with others. Although several studies discussed in this Chapter revealed how the visual mode plays a vital role in science education, some studies warn that visual mode can also be an impediment to learning. Finally, intersemiotic complementarity was discussed. It was discussed that intersemiotic complementarity explores the co-occurrence of two or more semiotic modes (e.g. in a science discourse). Although both the verbal and visual modes can communicate meanings independently, it was acknowledged in this Chapter that the two can also co-occur to communicate a coherent multimodal discourse. Chapter three presents the theoretical and analytical frameworks of this study.

CHAPTER THREE: THEORETICAL FRAMEWORK AND ANALYTICAL FRAMEWORK

3.1. Introduction

In this Chapter, I present the theoretical perspectives of the study. The study is theoretically framed by Social Constructivism and analytically framed by Systemic Functional Linguistics (SFL). I will first outline the notions of theoretical and analytical frameworks before discussing Social Constructivism and SFL.

Eisenhart (1991, p. 205) defines a theoretical framework as “a structure that guides research by relying on a formal theory, constructed by using an established, coherent explanation of certain phenomena and relationships”. Borgatti (1999) explains it as a collection of interrelated concepts, that guides research and determines things that will be measured. Richard (2013) reminds us that the theoretical framework presents and describes aspects of drawing from a theory that are relevant to the research problem under investigation. Sinclair (2007) likens a theoretical framework to a map or travel plan. Sinclair (2007) explains that when travelling to an unfamiliar country, people search for as much knowledge as possible about the best way to travel, mostly by using previous experiences, and ask others who have been on similar trips. This helps them to determine what they have to bring along that may help them have a successful journey and achieve their objectives (Sinclair, 2007). Before beginning a research

study, it is important to consider appropriate theories underpinning the knowledge base of the research focus (Sinclair, 2007). This will help to connect the researcher to existing knowledge. It will also help to explain, predict, and understand the research focus (Sinclair, 2007).

An analytical framework is a set of checklists of skills, tools, and techniques that are necessary for researching a particular area (Lieberman, 2007), such as analysis of multimodal discourse. Grant and Osanloo (2014) reveal that the analytical frameworks provide the structure to define how a researcher will analytically approach the study. It also provides the basic vocabulary of concepts and terms that researchers can use to construct fundamental explanations expected of a theory (Coral & Bokelmann, 2017). Moreover, the analytical framework helps in organising research and providing variables that will be used in the analysis of data (Coral & Bokelmann, 2017). In other words, the researcher's choice of an analytical framework provides structure and a common world view or lens from which to support one's thinking on the analysis of data (Grant & Osanloo, 2014).

Stanley (2012) argues that while the purpose of a theoretical framework is to reflect reality, an analytical framework helps to categorise and reduce inherent complexity of research. The aim of the theoretical framework in research is to explain the world (Bale, 2006). On the other hand, the aim of an analytical framework is to generate explanations to make simplifying assumptions (Stanley, 2012).

3.2. Social Constructivism

Social constructivism is a theory of knowledge and communication (Amineh & Asl, 2015). The phrase was coined by Peter L. Berger and Thomas Luckmann in their 1966 book, *The Social Construction of Reality* (Berger, Luckmann & Zifonun, 2002). The theory examines the knowledge and understanding of the world developed through the interactions between people and their environment (Amineh & Asl, 2015). Social constructivism is based on specific assumptions about reality, knowledge, and learning (Kim, 2001). It purports that reality is constructed through human activity (Kim, 2001), in which the members of the society invent

the properties of the world together (Kukla, 2000). Social constructivists view knowledge as a human product, which is socially and culturally constructed (Ernest, 1998). Meaning is created as individuals interact with each other and the environment in which they live (Kim, 2001). Learning is viewed as a social process – it does not simply occur within an individual, but takes place when individuals are engaged in social activities (Kim, 2001).

From a social constructivist viewpoint, science knowledge is not absolute (McComas, Almazroa & Clough, 1998), but symbolic and socially negotiated (Lee, 2006). Social constructivists see learners as an integral part of the learning process (Wertsch, 1997). In a constructivist learning environment, learners are actively involved in learner-centred learning activities (Gray, 2002). Group work and discussions are important in a constructivist classroom, as they encourage and engage learners in achieving the expected learning outcome (Jonassen, 1999; Surgenor, 2010). Learners construct their own meaning by matching and incorporating new ideas and experiences against existing knowledge (Surgenor, 2010). Learning is active (Bauersfeld, 1995), with learners discovering principles, concepts, and facts themselves (Brown & Palincsar, 1989). They do this through interacting with each other and the environment in which they live (Vygotsky, 1978). The environment referred to here can be the learning environment created by the teacher using certain learning materials and communication modes. The teacher is seen as a facilitator that helps learners to develop their own understanding of the science content. A teacher's role is to design lessons that promote discussion, active learning, and reflections, and provide modelling, coaching, and scaffolding to students when needed (Surgenor, 2010).

Vygotsky is one of the most influential theorists in social constructivism. Vygotsky's greatest contribution to social constructivism is the *Three Principal Assumptions* (Cheng & Cheng, 2012). The first assumption is that the members of a community play an integral role by interacting with individuals, which will influence individuals' views of the world (Vasireddy, 2007). Vygotsky believes that "cognitive growth occurs first on a social level, and then it can occur within the individual" (Amineh & Asl, 2015, p. 13). It is also stated in Vygotsky's general genetic law of cultural development that the higher psychological structures such as scientific knowledge appears first between people as inter-psychological (social) and then inside the child as intra-psychological (personal) (Vygotsky, 1978).

The second assumption is that the type and quality of mediating tools determine the pattern and speed of cognitive development (Vasireddy, 2007). Mediating tools include the more knowledgeable other (MKO) such as science teacher, visuals (Well, 1994) such as drawings employed by the science teacher, and language (Vasireddy, 2007) such as science-teacher talk. Vygotsky believes that language is the most important means through which people construct reality (Leeds-Hurwitz, 2009). On the social level, language is used to develop meanings between individuals while on the personal level, language is used as a mediation tool that enables individual cognition (Scott, 1998).

The third assumption involves the zone of proximal development (ZPD). Vygotsky believed that learning takes place in a sequential process from the current intellectual level of a learner to a higher level, which spans the learner's ZPD (Vygotsky, 1978). ZPD is defined by Vygotsky (1978, p. 86) as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers". As the adult guidance in a Physical Science classroom, the teacher has the responsibility of choosing the most appropriate teaching materials and teaching methods. The teacher has to consider effective language use, as well as the use of visuals in teaching and learning of scientific concepts.

Vygotsky believes that human psychological processes (which he called *high mental processes*) are mediated by psychological tools such as language, signs and symbols (Karpov & Haywood, 1998). Karpov and Haywood (1998) note that it is the duty of adults to teach these tools to children in order for children to internalise them, in order for the tools to function as mediators of children's more advanced psychological processes. Vygotsky (1978) suggests two types of mediation, which he regards as the main mechanism of children's learning and development – metacognitive mediation and cognitive mediation. "Metacognitive mediation refers to the acquisition of semiotic tools of self-regulation" (Karpov & Haywood, 1998, p. 27). With the help of semiotic tools, learners can undertake self-planning, self-monitoring, self-checking, and self-evaluating (Brown, 1987). Metacognitive mediation includes joint activities with learners, where an adult (or MKO) uses semiotic tools to regulate the learners' behaviour

– for example, when a teacher says ‘No’ to prevent a learner from tasting a chemical in the laboratory.

“Cognitive mediation refers to the acquisition of scientific concepts representing the essence of some class of phenomena” (Karpov & Haywood, 1998, p. 27). Children’s systematic cognitive mediation begins when they go to school and start to acquire scientific concepts (Karpov & Haywood, 1998). Vygotsky (1987) contrasted scientific concepts with spontaneous concepts. Spontaneous concepts are unsystematic, empirical and non-conscious concepts that result from generalisation and internalisation of everyday personal experiences (Karpov & Haywood, 1998). On the other hand, scientific concepts are the generalisation of the experience of humankind obtained in the course of systematic instruction (Karpov & Haywood, 1998). Once a learner acquires scientific concepts and internalises them, these concepts will act as mediating tools for learners’ problem solving (Vygotsky, 1987).

Social constructivism emphasises the importance of culture and context (Kim, 2001). In other words, social constructivism perceives the importance of the context in which learning occurs and the social context that learners bring to the classroom (Kim, 2001). Culture and context are essential in understanding what occurs in society; and knowledge is constructed based on that understanding (McMahon, 1997). Palincsar (1998) suggests that teaching should be shaping the response of the learners by using teaching approaches such as modelling and demonstrations. Visuals such as images and animations may provide some means for the modelling and demonstrations advocated by Palincsar. Baumann (1988) adds that a social constructivist teacher not only tells but shows, models and demonstrates skills and concepts to be learned.

The relevance of social constructivism to this study is its assumption that human beings rationalise their experience by creating a model of the social world and the way that it functions (Leeds-Hurwitz, 2009). Social constructivists highlight that individuals cannot discover reality because reality does not pre-exist prior to their social invention of it (Amineh & Asl, 2015). “Individuals make meanings through the interactions with each other and with the environment they live in” (Amineh & Asl, 2015, p. 14).

Social constructivism is also applicable to this study due to its concept of ‘mediation’ as the main mechanism of children’s learning and development (Karpov & Haywood, 1998). Both of the two major types of mediation, metacognitive mediation and cognitive mediation are applicable in this study. The study is looking at how teachers integrate the verbal and visual modes to make meanings. The verbal and visual modes in that sense are acting as mediation tools. As stated earlier, human psychological processes – higher mental processes, “are mediated by psychological tools such as language, signs, and symbols” (Karpov & Haywood, 1998, p. 27). According Vygotsky (1977), these tools are introduced to children in joint activity. When the children internalise them, the tools will function as mediators of the children’s more advanced psychological processes (Karpov & Haywood, 1998). As mentioned earlier, mediating tools include important adults – the MKO. In terms of this study, the MKO are Physical Science teachers. As the MKO in Physical Science classroom, teachers are expected to regulate the learners’ behaviour in the course of joint activity.

3.3. Systemic Functional Linguistics (SFL)

Systemic functional linguistics (SFL) is an approach to linguistics that considers language as a social semiotic system (Banks, 2002). According to Halliday and Matthiessen (2004), the term systemic means that the grammar consists of system networks that comprise the pattern of choices through which people make meaning. SFL started with the work of Malinowski (1923), who contributed to the study of meaning from ethnographic and linguistic perspectives, as well as developing ideas about context of culture and context of situation. After two decades, it was furthered by Firth (1951, 1957), who developed a theory of system-structure. Firth’s student Michael Alexander Kirkwood Halliday (often called M.A.K. Halliday) developed the theory fully during the 1960s in the United Kingdom, and later in Australia (Almurashi, 2016). Researchers such as Hasan, Martin, Matthiessen, Kress, van Leeuwen, and Royce further expanded the theory that is today known as SFL. While most linguistic theories today are more concerned with language as a mental process, SFL focus on exploring how language is used in social contexts to achieve particular goals (O’Donnell, 2011). The theory looks at the discourses we produce (whether spoken or written), and the contexts of the production of these texts (Halliday 1978). Halliday’s approach to language is widely used, especially in language education, and for discourse analysis (Almurashi, 2016).

Halliday (1978) proposes that language has three metafunctions – the *ideational*, *interpersonal*, and *textual* metafunctions. Halliday’s ideational metafunction expresses two ideas, the experiential and the logical content of the text. The textual function is language-oriented – it deals with how language is organised and structured to form a cohesive and coherent text. The Interpersonal function deals with the social and power relations among language users, “It relates participants’ situational roles to the discourse produced” (Halliday & Martin, 1981, p. 328). As mentioned in Section 2.6, this study used the ideational meanings to analyse the intersemiotic complementarity of the verbal and visual modes in Physical Science classrooms.

Halliday (1978) views language as a social semiotic. For Halliday “the internal organization of language is not arbitrary but embodies a positive reflection of the functions that language has evolved to serve in the life of social man” (1973, p. 26). This tells us that language expresses meanings that are created within a social system (Fontaine, 2012). Urban (1981) adds that language is seen as a device designed for achieving communicative ends. Furthermore, Halliday (1978) argues that languages, dialects and registers differ both in form and in meaning potential. O’Grady et al. (2001) define dialect as a regional or social variety (style) of language characterized by its own phonological, syntactic, and lexical properties. Shareah, Mudhsh, and AL-Takhayinh (2015) note that a dialect is normally determined by a speaker’s geographical background – it is associated with some social groups and ethnicity. A register is a variety of language used for a particular purpose or in a particular social setting (Ottenheimer, 2006). While dialects are associated with particular speech of communities and geographical settings, registers are associated with language used for particular purposes or particular situations. (Shareah, Mudhsh, & AL-Takhayinh, 2015). This reminds us that language is socially and culturally situated. The meaning produced by speakers of a certain language depends on how they use the language and where they are using it.

Although much of the Hallidayan SFL model is utilised in social linguistic analysis of natural language, O’toole (1995) argues that the SFL model “offers a powerful and flexible model for the study of other semiotic codes” (p. 159). Similarly, Royce (1999) highlights that SFL has valuable application to multimodal forms of communication. This is aligned to Hasan (1993, p. 94), who earlier notes that “systemic functional linguistics attempts to integrate language as a semiotic system with other semiotic systems in the community”.

SFL has strength in analysing verbal-visual intersemiotic complementarity because the three metafunctions permit analysis from the three different perspectives (Royce, 1999). The social semiotic view of the communication constituent in the SFL model which was adopted for this study emphasises that whether the communication contains only verbal mode, visual mode, or both the verbal and visual modes, “it is viewed as embodying the pattern of purposeful choices made by its constructors in order to make meanings for others to receive and respond to in some way” (Royce, 1999, p. 124).

As with linguistics and other social semiotics, it is assumed that each visual involve choices which are available to the producer/user of that visual (Royce, 2007). Halliday (1978) points out that communication involves making selections from the system of meaning in terms of what is going on (the field- realised ideationally), who is taking part (the tenor- realised interpersonally), and the role assigned to language (the mode- realised textually). Royce (2007) concludes that the intersemiotic ideational metafunction realises the *field* component of the context, the intersemiotic interpersonal metafunction realises the *tenor* of the relationships between the interactants, and the intersemiotic compositional (*textual*) metafunction realises the Mode. Royce (1999) thus suggests that the Hallidayan view of communication can be useful to systems of meaning beyond language in just a spoken and written sense.

The ideational metafunction can be examined in terms of the cohesion that occurs between the verbal and visual modes, achieved through sense relations. “The concept of cohesion is a semantic one” (Halliday and Hasan 1976, p. 4). In this study cohesion refers to the relation of meanings that exist across the verbal and visual modes. The result of the chains of related words that contribute to the continuity of lexical meaning is called lexical cohesion (Morris & Hirst, 1991). Halliday and Hasan (1976) divide lexical cohesion into two categories, reiteration and collocation. “Reiteration is a form of lexical cohesion which involves the repetition of lexical items” (Sari, 2012, p. 14). Reiteration also includes the use of synonymy, antonymy, hyponymy and meronymy. Collocation is concerned with the relationship between words that often occur together (Renkema, 2004). This study uses repetition, synonymy, antonymy, hyponymy and meronymy as intersemiotic sense relations for analysing the intersemiotic complementarity between the verbal and visual modes in science teachers’ classroom practice. These sense relations are also used by Kress and van Leeuwen (1990) to analyse visuals, and Royce (1999)

to analyse visual-verbal intersemiotic complementarity in a magazine. Collocation is used by Kress and van Leeuwen (1990) as well as by Royce (1999), but I decided not to include it in the analysis of intersemiotic complementarity in this study. This is because most of the lexical items which are commonly used together were already covered by the other sense relations mentioned above.

In this study, the intersemiotic sense relations give a description of the nature of the intersemiotic semantic relationship between the visual messages and the identified lexical item (Royce, 1999). That relationship is expressed in Figure 1.

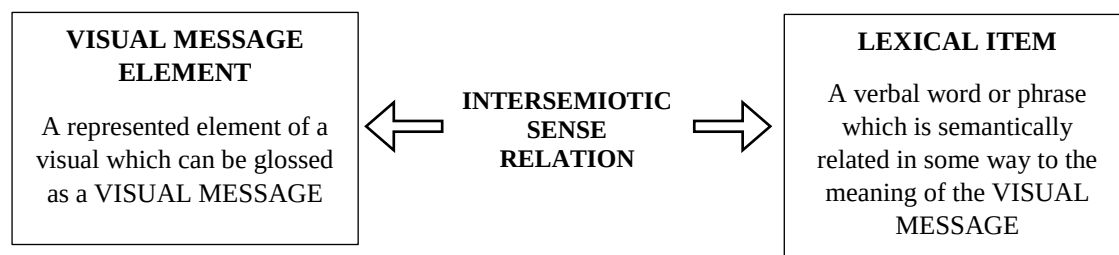


Figure 1: Intersemiotic sense relations (Royce, 1999)

The SFL approach to verbal (language) and other semiotic modes, specifically the metafunctional meanings offers a framework by means of which the intersemiotic complementarity of the verbal and visual modes in Namibian Physical Science teachers' classroom practice can be examined and analysed. The ideational metafunction is the metafunction that plays a vital role in the analysis of data in this study. It examines the cohesion that occurs across the verbal and visual modes through the sense relations: repetition, synonymy, antonymy, hyponymy and meronymy which are discussed in the following sections.

3.3.1. Intersemiotic Repetition

Intersemiotic Repetition involves the repeated use of lexical items which express the same meaning represented in two different semiotic modes (Royce, 1999). It is used by Royce (1999) to examine and analyse visual-verbal semantic interface in a representative multimodal text

from the Finance department of *The Economist magazine*. Although Royce's study focused on magazines, his findings can help us to understand how we can better integrate the verbal and visual modes in a semantic way. In relation to verbal-visual intersemiotic complementarity in science classrooms, Intersemiotic Repetition involves the repetition of a lexical item which express the same meaning represented both in verbal and visual aspects (Royce, 1999). Royce (2002) gave examples that if the verbal message is 'positive' and the visual message is also 'positive', then the two modes realise intersemiotic complementarity through Intersemiotic Repetition. In the case of this study, repetition focuses on lexical items in the teacher's verbal explanation which expresses the same meaning represented in the visual mode.

Royce (1999) also reveals that Intersemiotic Repetition includes items that are morphologically distinct due to inflexion or derivation. Inflexion in Royce's analyses of visual-verbal intersemiotic complementarity in *The Economist magazine* includes the sequence 'supply', 'supplies' and 'supplied', derivation can be seen in 'supply' and 'supplier'. If the verbal message is 'supply' and the visual message is 'supplies', the two modes still realise intersemiotic complementary through Intersemiotic Repetition. Lexical items that are morphologically distinct are also applicable in the science classroom and other multimodal discourses. When teaching Physical Science, teachers can include the same messages in both the verbal and visual modes for intersemiotic complementarity to be realised – for example, a visual showing 'particles' of a certain substance and a verbal mode referring to 'particles'. Apart from using perfect match meanings in both modes, teachers can also use items that are morphologically distinct due to inflexion – for example, 'electron and electrons', or due to derivation – for example, 'heat' and 'heater'.

Intersemiotic repetition of the verbal and visual modes can also be realised through homospatiality. Homospatiality refers to "a type of spatial parallelism between language and pictures on the visual mode and 'parallel structures' on the verbal mode" (Baykal, 2016, p. 54). In multimodal science discourse, homospatiality refers to two different semiotic modes (e.g. verbal and visual) co-occurring in one spatially bonded homogenous entity – the structure (space, position, area or size) of what is represented in a visual is the same as what is represented by the verbal mode (Unsworth, 2006). Unsworth (2006) gives an example of a

verbal representation, ‘snaap’, which visually appears with the ‘sna’ segment and the ‘aap’ segment separated (see Figure 2). In this example, the word snaap itself has “snapped”.

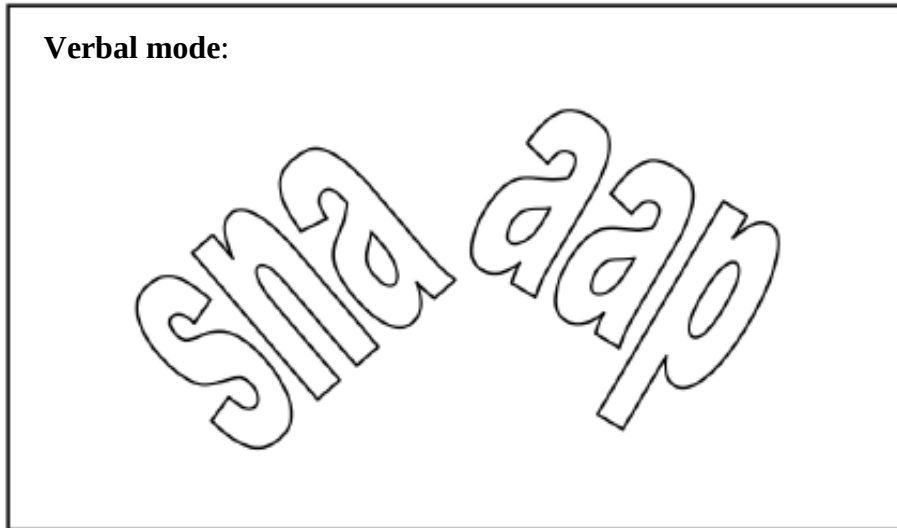


Figure 2: Intersemiotic repetition through homospatiality (Unsworth, 2006)

3.3.2. Intersemiotic Synonymy

Greenbaum (1996, p. 420) defined synonymy as “expressions that are identical or similar in meaning and that can be used interchangeably in at least one context”. Similarly, Bahaziq (2016) defines synonymy as items that have similar meaning such as, attractive and beautiful. Therefore, Intersemiotic Synonymy refers to meaning of the two lexical items which are similar (Royce, 1999). Intersemiotic Synonymy is used by Royce (1999) in his analyses of visual-verbal intersemiotic complementarity in *The Economist magazine*. Royce argues that “the meaning of the two lexical items need to be the same or almost the same, and may often be used interchangeably” (1999, p. 143) for intersemiotic complementarity to be realised through intersemiotic synonymy. Although Royce and a number of scholars use synonymy to refer to meanings which are the *same*, in this study I used it to refer to meanings which are *similar*. This helped to differentiate synonymy from repetition, which refers to meanings that are exactly the same.

In Royce's study, synonymous is observed in the relations between 'trade cycle' and 'business cycle', and between market structure definitions such as 'perfect competition' and 'pure competition'. 'Trade' and 'business' are two different terms, but they mean the same thing in economics, the same applies to 'perfect' and 'pure'. When using intersemiotic synonymy, the terms do not necessarily need to be exactly the same, as long as they are similar. Another example of intersemiotic synonymy is given by Royce (2007) where an image of a scientist glossed (referred to) as 'scientist' is intersemiotically synonymised by the lexical item 'researcher' in the verbal mode. In this case, the terms scientist and researcher have a similarity relation - they refer to a certain person.

In terms of verbal-visual intersemiotic complementarity in a Physical Science classroom, teachers can use intersemiotic synonymy by showing a visual which can be glossed as 'zero charge' and a verbal referring to 'neutral charge'. In covalent bonding, terms like 'share equally' and 'fifty-fifty' can be regarded as synonymous. Intersemiotic synonymy might be crucial in science discourse because it can help teachers to avoid repeating the same word over and over. Furthermore, sometimes words in the visual messages might not be the most appropriate words to be used in the verbal messages. In such cases, teachers need to find synonyms to use.

Intersemiotic synonymy includes the use of 'ideational concurrence' - the equivalence between the verbal and visual modes (Unsworth, 2006). The specific relation of ideational concurrence under intersemiotic synonymy is described by Martinec and Salway (2005) as 'exposition' – "where the image and the text are of the same level of generality" (p. 350). In other words, exposition is when the meanings of the verbal mode or visual mode are re-expression in the alternative mode (Unsworth, 2007). Unsworth (2006) gives an example (see figure 3), where an image translated as: "Hannah is reading a book about gorillas while sitting on the floor" concurs synonymously with the verbal text: "She read books about gorillas". In this kind of relation, science teachers are expected to re-express meanings in a different mode using similar meaning.

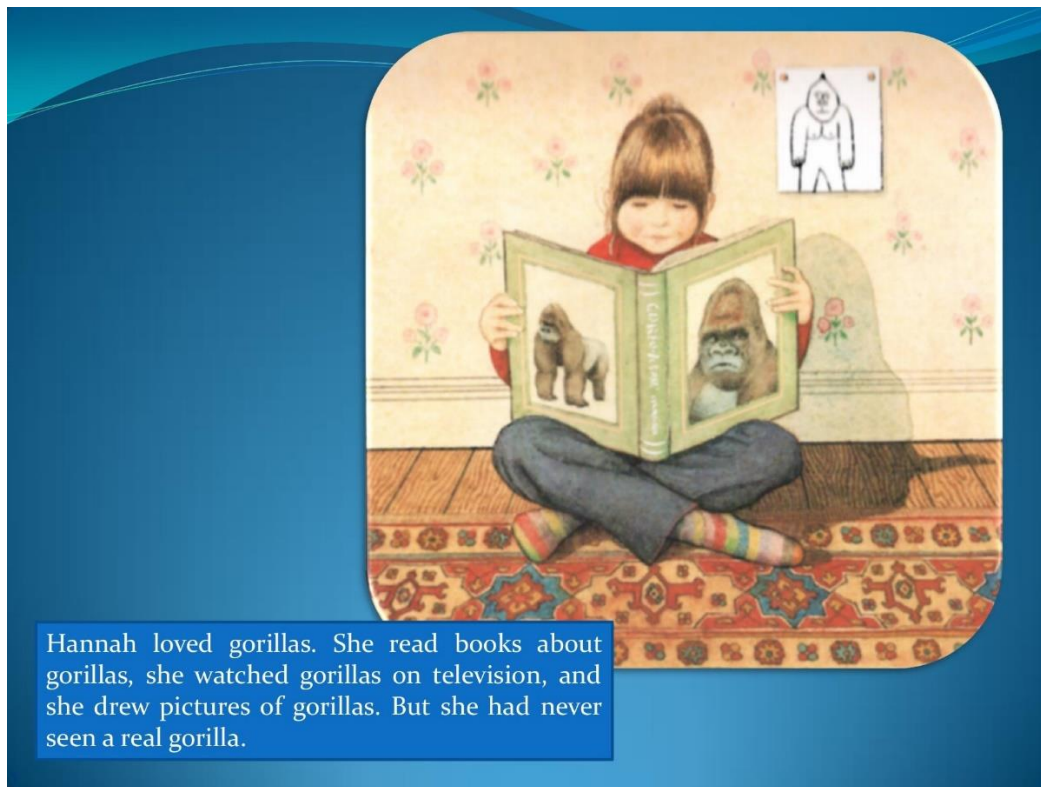


Figure 3: Intersemiotic repetition through exposition (Browne, 1983)

Another way in which science teachers can use intersemiotic synonymy is through ‘extension through similarity’. Drawing on Halliday’s SFL, Van Leeuwen (2005) used ‘extension’ to express relations where images extend or change the meaning of an accompanying text. Maier, Kampf and Kastberg (2007) used ‘extension’ to look at relations where the visual mode extends the meaning of the verbal. Extension through similarity in terms of verbal-visual intersemiotic complementarity is when the visual mode extends the meaning of the verbal mode by using similar meanings. Extension through similarity can give learners the opportunity to visualise what is verbally constructed. That communication strategy promotes continuous relations between the verbal and the visual modes (Maier et al., 2007).

Intersemiotic synonymy also includes situations where one semiotic mode works as a translation of the other. Although the term translation is commonly defined as a verbal practice of changing what is spoken in one language into another language (for example, see Hawkins & Allen, 1991), translation can also occur between different semiotic modes and such instances are termed ‘intersemiotic translation’ (Torresi, 2008). According to Kourdis (2015)

intersemiotic translation involves translation from one semiotic system to another, verbal or nonverbal. In terms of verbal-visual intersemiotic complementarity, the translation is from verbal to visual mode or vice versa. Intersemiotic translation is vital in a science classroom considering Torresi's (2008) suggestion that in today's communication any lexical item (like a word, phrase or sentence) remains an abstract phenomenon if it is isolated from a visual. This tells us that Physical Science teachers need to translate the content of some verbal items into visuals to support learners to make sense.

When Physical Science teachers use intersemiotic translation to represent verbal information of abstract and new concepts through visuals, it might help learners to make meaning of what they are learning. Consequentially, learners are likely to be interested in what they are learning, leading to the realisation of one of the aims of the Namibia Basic Education Curriculum which aims at enabling learners to think scientifically and apply scientific knowledge in different aspects of life (MoE, 2009).

3.3.3. Intersemiotic Antonymy

Antonyms are words that have opposite meanings – for example, 'fast' and 'slow'. Generally, human beings tend to polarise experience and judgement – they often think in opposites (Lyons, 1968). This can be confirmed by the existence of a large quantity of antonyms (Gao & Zheng, 2014) not only in the English language, but also in scientific language. For example, for learners to understand the concept of speed, teachers often use changes in time taken to travel a certain distance. If the speed increases, the time taken decreases and vice versa. Intersemiotic antonymy is when the meaning of two semiotic modes are in opposition (Royce, 1999). In Royce's study, the antonyms observed included such things as 'long run' and 'short run', 'increasing returns to scale' and 'decreasing returns to scale', 'buyer' and 'seller'. Royce (2002) gives an example of a graph showing increased temperature as a function of time, captioned as 'increases over time'. Such a graph is intersemiotically related through antonymy to the lexical item 'decreases'. In terms of this study, intersemiotic antonymy is looking at the opposite meanings coming through across the verbal and visual modes.

In a Physical Science classroom, the use of intersemiotic antonymy could be beneficial to the acquisition of scientific knowledge. Some concepts in science require teachers to use opposite words in the verbal mode and the visual mode – for example if a teacher is teaching friction force, words like ‘forward’ and ‘backward’ can be used to express the direction of motion and friction force respectively. Other examples of antonymy in a Physical Science classroom might be observed when working with resistance in the topic of electricity. A visual showing an ‘increase of the thickness of a conductor’ can be verbally referred to ‘resistance decreases’. Other examples of intersemiotic antonymy that can be observed in a Physical Science lesson are ‘an atom losing electrons’ and ‘an atom gaining electrons’; and ‘increasing speed’ and ‘decrease in time taken to destination’.

Unsworth (2006) has also drawn attention to the role of opposite meaning of two semiotic modes. In his category of image-text ideational complementarity, he used the term ‘ideational divergence’ to represent instances where the meaning of the image and the text are opposite to each other. “Divergence refers to cases in which several components deploy in parallel, dissimilar and sometimes contradictory messages” (Vorvilas, 2014, p. 29). For example, the ideational divergence in a science classroom given in Unsworth’s (2007) study of language-image interaction is shown in Figure 4.

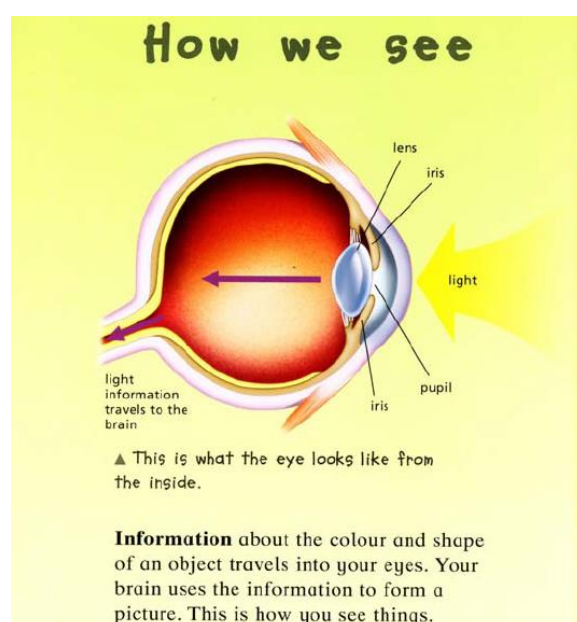


Figure 4: Intersemiotic synonymy through ideational divergence (Unsworth, 2006)

In the example given in Figure 4, the message ‘how we see’ is represented in the visual mode and language (text) mode. The ‘information about the colour and shape of an object’ is varied in the visual mode to ‘light’. In other words, there is a diversity between what the text is conveying and what the visual mode is showing.

3.3.4. Intersemiotic Hyponymy

Hyponymy is defined by Bankova (2015, p. 40) as a “relation between two concepts - X (the super-ordinate) and Y (the hypernym), i.e. X and Y are in a super-ordinate – hypernym relation if X is a type of Y”. Earlier, Kempson (1977) explained that for a lexical item P to be defined as a hyponym of Q, all the features of Q need to be contained in the specifications of the features of P. In other words, hyponymy is the relation between a general class of something and its subclasses (Royce, 2007). Therefore, intersemiotic hyponymy is the classification of the cohesive relations between a general class (the super-ordinate), and its sub-classes (the co-hyponyms), and vice versa (Royce, 1999).

In his examination of visual-verbal intersemiotic complementarity, Royce (1999) used intersemiotic hyponymy to classify the cohesion relationship between a general class in visual message and its sub-classes in verbal, and vice versa. In Royce’s (1999) study, intersemiotic hyponymy is observed where a visual message is ‘UK banks’, and the lexical item in the verbal aspect is ‘Lloyds bank’. This is an example of hyponymy because UK banks is expressing a general class (super-ordinate), and Lloyds bank refers to a specific bank in UK (hyponymy). Royce (2002) gives another example of intersemiotic hyponymy, where a sketch showing various types of marsupials in desert areas, glossed as ‘marsupials’, is intersemiotically related through hyponymy to the lexical ‘kangaroo’ (a type or subclass of marsupial). In terms of verbal-visual intersemiotic complementarity in a Physical Science classroom, a general class can be ‘chemical element’ and its sub-class can be ‘alkali metal’. The general class of *gasses*, can have a sub-class of noble gases.

Zhan and Wang (2015) propose the use of the concepts C1 and C2 when dealing with hyponym words when it comes to the acquisition of knowledge. When dealing with the concepts C1 and C2, “if the extension of C2 includes the extension of C1, then C1 and C2 can be thought to have a hyponymy relation, and we can say C2 is the hyponymy concept of C1, and C1 is the hyponymy concept of C2” (Zhan & Wang, 2015, p. 1). They further explain that the lower and upper concepts C1, C2 form a hyponymy relation and that hyponymy relation is denoted ISA(C1, C2). ISA is a relationship used to model the hierarchy which is created as the class entity decomposed into its logical sub-components (Burleson, 2017). One easy way of judging if an ISA(C1, C2) relation exists or not is to judge if the sentence itself of ‘C1 is a kind of/is one of C2’ is correct (Zhan & Wang, 2015). For example in Physical Science, ‘sodium is a kind of a metal element’ is correct, therefore ISA(sodium, metal element).

Intersemiotic hyponymy is crucial in the acquisition of scientific knowledge. It contributes to the ability of learners to memorise terminologies efficiently, both in short-term and long-term aspects (Peng, 2016). Kocherhan (2006) demonstrates that this is possible because the organisation order of vocabularies and terminologies in a subsystem of concepts are developed in a specific characteristic with other terms within the same terminological system. In other words, “the meaning of a word depends on its position in the lexical-semantic system” (Azarova & Radomska, 2013, p. 116). Barrière (2004) agrees that the relationship between terms is crucial in the learning of new terminologies. The semantic relations of ISA(C1, C2) is highly informative and is a good approach to the teaching of new terminologies in a Physical Science classroom since the hyponym words provide conceptual information and domain knowledge (Meyer, 2001). The use of hyponym words in Physical Science lessons help teachers to organise semantic relations in the form of knowledge patterns (Barrière, 2004).

3.3.5. Intersemiotic Meronymy

Royce (1999) identifies intersemiotic meronymy as another sense relation that contributes to the effective practice of verbal-visual intersemiotic complementarity. Meronymy refers to the relation between a concept/entity and its constituent parts. This relation is also referred to as part-whole relation and paronymy (Khoo & Na, 2006). Meronymy and hyponymy might be confused so Khoo and Na (2006, p. 171) distinguish them by stating that “hyponymy relations

can be said to exist within concepts, while meronymy relations are between concepts”. In his study of visual-verbal intersemiotic complementarity, Royce explained meronymy as “a classification of the cohesive relations between the whole of something (termed the super-ordinate) and its constituent parts (termed the meronyms and co-meronyms)” (Royce, 1999, p. 144). This cohesive relation is observed in Royce’s study where a table of the ‘US economy’ sectors is represented in the visual mode, while the verbal lexical item referring to the specific sector is ‘car production’. The meronym here is ‘US economy’, while the co-meronym is ‘car production’.

Intersemiotic meronymy can be used by Physical Science teachers to express meaning which has a part-whole relation. Royce (2002) gives an example from a Physical Science classroom, where a schematic diagram showing an energy-efficient house, glossed as the meronym ‘energy-efficient house’, is intersemiotically related through meronymy by the lexical item ‘solar panels’ (referring to specific parts of the energy-efficient house). In school Physical Science, if the super-ordinate is ‘atomic structure’, its constituent part can be ‘electron shells’.

3.4. Links between Systemic Functional Linguistics (SFL) and Social Constructivism

Systemic functional linguistics (SFL) and social constructivism are compatible theories. The two share a number of common interests. SFL concentrates on how learners simultaneously engage in language and learn through language – it is a prototypical form of human semiotic mode, and how social semiotics helps make meaning (Halliday, 1993). Furthermore, SFL sees language as an essential condition in the learning of learners - it is a process by which experience becomes knowledge (Halliday, 1993). As discussed earlier, Vygotsky viewed language as a semiotic tool that mediates learning (Wells, 1994). Although Vygotsky recognised the variety of semiotic forms, he undoubtedly considered language to be of great significance (Wells, 1994). He believed that language functions as a mediator of social activity by enabling teachers to plan, coordinate and review their actions (Vygotsky, 1987).

Halliday and Vygotsky spent much of their time attempting to improve the quality of children's educational experience. Despite differences in their focus, their work makes a significant impact in the field of education - Halliday in terms of linguistics and Vygotsky in terms of psychology. Both SFL and social constructivism view language as a semiotic mode/tool. Halliday and Vygotsky see the learning process as being performed through conversational interaction (Wells, 1994). They see language as a human invention which is used as a means of achieving the goal of social living (Wells, 1994). Furthermore, both Vygotsky and Halliday see language as a cultural tool (Wells, 1994). Both also emphasise the part language plays in the development of a member of a particular culture. Halliday's functional approach to language gives emphasis to both system and behaviour. That provides support to the explanation of how conversational interaction leads to language development (Wells, 1994). Vygotsky's last stage in the internalisation of social conversation – characterisation of language as inner speech, emphasises the importance of parents and teachers in the learning process (Vygotsky, 1978). While Vygotsky's main target is an explanation of individual mental functioning, Halliday targets the natural language and organisation of language as a resource for human social living (Wells, 1994).

Halliday and Vygotsky believe that the best way to understand language is by adopting a genetic approach to the study of the way language functions in a situation where it is used as a tool (Wells, 1994). While Halliday views language as a social semiotic and one of the semiotic systems that create a culture, Vygotsky develops an insight of semiotic mediation that sees language as a semiotic tool (Halliday, 1978; Wells, 1994). Language as a social semiotic can be interpreted within a sociocultural context, where culture itself is interpreted in semiotic terms – as an information system (Wells, 1994). Social semiotics and semiotic tools have a dual nature as artefacts: “They are simultaneously both material and ideal, and so require of their users both physical and intellectual activity” (Wells, 1994, p. 48).

Both Halliday and Vygotsky recognise that schooling is very much concerned with the development and reconstruction of meaning (Wells, 1994). Nevertheless, they analyse meaning differently, especially in their choice of units of analysis (Wells, 1994). While Halliday sees a text as a minimum unit of analysis (an instance of language being used in discourse), Vygotsky focuses on word meanings as the locus of conceptual development (Wells, 1994). To Halliday,

meaning is made in the constructing and interpreting of texts, and this involves the interplay of interpersonal meaning, textual meaning, as well as logical and experiential meaning (Wells, 1994; Royce, 2007). Halliday believes that language is the essential condition of knowing, where experience becomes knowledge (Halliday, 1978). His focus was on studying how learners use resources to engage in learning language and learning through language (Wells, 1994).

3.5. Chapter summary

In this Chapter, I discussed the theoretical framework that I used to inform this study and the analytical framework that I used to analyse data. I looked how social constructivism views learning as socially and culturally situated, and how the environment influences learning. Social constructivism also emphasises the importance of mediating tools. Mediation tools include verbal language and visuals. In Chapter Three, I also deliberated the SFL theory that views language as a social semiotic. Recent scholars used Halliday's SFL approach to language to analyse semiotic modes other than language – for example, visuals. Some scholars have paved the way for using an SFL approach to analyse the intersemiotic complementarity between language (verbal) and visuals. Chapter 4 presents the research methodology of this study.

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1. Introduction

There is no universal approach to research methodology when designing a study on the production of knowledge. There are different research methods that can be employed to conduct research with certain aims. Research is also underpinned by philosophical assumptions about what constitutes validity (Thomas, 2010). The main research question for this study was: What is the nature of the verbal-visual intersemiotic complementarity of Physical Science teachers' classroom pedagogic practice in Namibia? In this Chapter, I provide details of research methodology for conducting this study. I discuss the research paradigm, research methods, sampling, data collection tools, testing of tools, and data collection procedures. In addition, I discuss approaches to data analysis, validity and trustworthiness, as well as ethical issues considered before, during and after the research.

4.2. Research paradigm

There are different beliefs that could underpin possible research (Scotland, 2012). Those beliefs can be referred to as paradigms. The term paradigm was first used by Thomas Kuhn in 1962, referring to a conceptual framework used by a group of scientists which provides a model for examining problems and finding solutions (Thomas, 2010). Kuhn (1977) defines a paradigm as an integrated cluster of substantive concepts, variables and problems attached with corresponding methodological approaches and tools. A paradigm refers to a set of beliefs, values, and assumptions that researchers have in common concerning the nature and conducting of research (Kuhn, 1977; Thomas, 2010). Bertram and Christiansen (2014) explain that a research paradigm is a researcher's worldview that defines what is acceptable to research and how the research should be done. A research paradigm helps a researcher to define valid research (Rahi, 2017). It is essential to select a specific paradigm because it guides researchers towards dwelling within a coherent philosophical frame during the study (Myers & Avison, 2002).

Bertram and Christiansen (2014) identify three key paradigms: the postpositivist, the interpretivist and the critical paradigm. They explain that postpositivist researchers describe, control and predict how the natural and social world work. Postpositivist emphasises meaning and the creation of new knowledge, and supports movements that aspire to change the world and contribute towards social justice (Ryan, 2006). Researchers within the critical paradigm aim to unpack the structural, political, cultural and historical reality in order to arrive at a change of an emancipatory nature (Bertram & Christiansen, 2014). Dammak (2015) adds that critical researchers emphasise the importance of the interactive relation between the researcher and the participants. In contrast, interpretivists believe that reality is multi-layered and complex (Dammak, 2010), and it can only be explored in its context. This study is underpinned by the interpretive paradigm for reasons that will now be discussed.

According to Rahi (2017) interpretivists believe that true knowledge can only be obtained by deep interpretation of a subject. Researchers using the interpretive paradigm want to understand how people make sense of their world (Bertram & Christiansen, 2014). The interpretive paradigm involves researchers striving to discover reality through participants' views, their background, and experiences (Yanow & Schwartz-Shea, 2011). The interpretive paradigm is often regarded as a qualitative research paradigm (Rahi, 2017) meaning that it commonly adopts qualitative approaches.

The aim of this study was to explore the dynamics of verbal-visual intersemiotic complementarity in the classroom practice of three Namibian Junior Secondary Physical Science teachers having different amounts of science teaching experience. The social constructivism theoretical framework informing this study offered insight into the importance of social semiotics to the mediation of learning, and how society influences learning. The systemic functional linguistics (SFL) theory, the analytical framework of the study, provided tools which can be used to analyse data in multimodal discourse. In order to answer research questions outlined in Section 1.8 of this study, a qualitative approach is employed. The aim of this study and the theoretical framework employed, support the use of qualitative methods for answering the research questions.

4.3. Research methods

This study is a qualitative case study of Namibian Physical Science teachers' classroom practice. Yin (1984 p. 23) defines the case study research method as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used.” The case study method allows research to explore and understand complex issues (Zainal, 2007). The method is useful for this study which strives to explicate the issue of verbal-visual intersemiotic complementarity of Namibian Physical Science teachers' classroom pedagogic practice.

Qualitative research is an “interpretive naturalistic approach to the world” (Denzin & Lincoln, 2005, p. 5). It uses methods that seek a deeper truth (Greenhalg & Taylor, 1997). Qualitative research helps us to understand the social life of a specific targeted population or place, in contrast with quantitative research which identifies large-scale trends (Crossman, 2017). Researchers using qualitative methods aim to study things in their natural setting (Denzin & Lincoln, 2005), in order to make sense of a phenomena in terms of the meanings people bring to them (Greenhalg & Taylor, 1997; Denzin & Lincoln, 2005). This type of study allows the researcher to examine the meanings that people attribute to their behaviour, actions, and interactions with others (Crossman, 2017). Although qualitative research creates in-depth understanding of the attitudes, behaviours, interactions, events, and social processes that compose everyday life (Crossman, 2017), samples are small and represent a narrow population making it difficult to know how much the results can be generalised (Bricki & Green, 2007). Regardless the small sample required for this approach Greenhalgh and Taylor (1997, p. 740) argue that “a good qualitative study will address a clinical problem through a clearly formulated question and using more than one research method (triangulation)”.

Yin (2009) reminds us that there should be an alignment between the research methods and the nature of each specific research question. The first research question of this study is about how Namibian Physical Science teachers use verbal-visual intersemiotic complementarity in their lessons. Lesson observations and interviews were used to examine how teachers integrate

verbal and visuals to communicate meaning. The purpose of the second research question was to see if there are correspondences between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience. The second research question is also answered by data obtained from lesson observations and interviews.

4.4. Research site and sampling

Qualitative studies require the development and maintenance of a close relationship between the researcher, research subjects and sites (Frankel & Devers, 2000). Cohen, Manion and Morrison (2011) indicate that the tools used in research determines the appropriateness of the sampling technique and definition of the population on which the research will focus. Appropriate sampling technique is one of the factors that determines the quality of the research (Cohen et al., 2011). Sampling involves making decisions about which people, setting, events or behaviours are to be included in the study (Bertram & Christiansen, 2014). Although researchers need to consider the population from which they are sampling, Bertram and Christiansen (2014) note that researchers working in different paradigms deal with sampling differently. Researchers within the interpretive paradigm are not concerned with statistical accuracy or whether the data can represent the entire population (Bertram & Christiansen, 2014). Their concern is in-depth description and analysis.

This study was carried out in the Oshana region of northern Namibia, where I work as a Junior Secondary Mathematics and Physical Science teacher. The Oshana region is one of the low performing regions when it comes to Physical Science in Namibia. The region failed to reach its target of a 60% pass rate for Grade 10 in the past five years (2013 – 2017) The region has both urban and rural schools. The study is conducted with three Junior Secondary Physical Science teachers at urban schools. Physical Science in the Namibian curriculum begins at Grade 8 and ends in Grade 10. Occurring just before the senior secondary grades (11 and 12), the Junior Secondary phase is seen as a crucial phase to develop scientific knowledge. The teachers were purposively selected according to their years of Physical Science teaching experience, the location of their schools, their teaching qualifications, as well as their willingness to participate in the study.

Teachers with different years of teaching experience were selected in order to explore possible correspondences between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of Physical Science teaching experience. All three schools are urban schools and all three participant teachers have at least a bachelor's degree or equivalent, in education specialising in Physical Science. The issues of the school location and teachers' qualifications were considered in order to avoid these factors influencing the results.

Jensen, Sandoval-Hernandez, Knoll and Gonzalez (2012) categorised teachers' teaching experiences into six groups: 0-2 years, 3-5 years, 6-10 years, 11-15 years, 16-20 years and more than 20 years. Based on this categorisation, 0-2 years of science teaching experience was the criteria for the least experienced research participant. 6-10 years was the criteria for the intermediate-experience teacher because the difference between 0-2 years and 6-10 years is likely to provide rich data compared to the difference between 0-2 years and 3-5 years. Similarly, my initial criteria for the most experienced teacher was more than 20 years or 16-20 years of Physical Science teaching experience. However, since I could not find a teacher with such experience in the targeted research site, my criteria were for a teacher with Physical Science experience in the 11-15 years range.

4.5. Data collection techniques

Data collection tools play an important role in any research project - they determine the success of the research, its validity and reliability (Alshenqeeti, 2014). This study employed lesson observations (involving video recording of lesson presentations) and interviews (semi-structured) for answering research question 1 – to explore how the Namibian Physical Science teachers use verbal-visual intersemiotic complementarity in their lessons, and question 2 – the correspondences (if any) between verbal-visual intersemiotic complementarity in classroom pedagogy and the number of years of science teaching experience.

4.5.1. Lesson observations

Observation is field research (Lofland & Lofland, 1995), used by researchers to “obtain real-time data about subjects’ behaviour, interactions, and experiences from the actual environment in which they naturally occur” (Picardi & Masick, 2013, p. 132). Data collected through observations are first hand data, because the researcher goes to the site of the study. In education, the site can be a school, a classroom, or a staffroom (Bertram & Christiansen, 2014). In the case of this study, it was 3 science classrooms. Through observation, the researcher witnesses and records for himself, instead of relying on the opinions or perceptions of others. This makes observation one of the most powerful methods of gaining insight into the situation (Bertram & Christiansen, 2014). Furthermore, observation provides a chance to learn things that people may be unwilling to discuss in an interview (Bryant, 2008). It is noted that the presence of the observer in the classroom is likely to change the behaviour of both the teacher and learners. That issue is addressed in the validity and trustworthiness section (Section 4.9).

All three teachers had their Physical Science lessons observed and video recorded. Four lessons per teacher were observed. During the observation, my focus was on how teachers used the verbal and visual modes in their classrooms towards learners constructing meaning. More specifically, I looked at the spoken language of the teacher when explaining concepts, in relation to the visual mode used on the chalkboard, in summaries, in posters and in handouts. Lesson observations in this study also looked at situations where a teacher could have used both the verbal and visual modes to communicate meaning, but neglected one or the other.

4.5.2. Semi-structured interviews

Mathers, Fox and Hunn (1998, p. 1) define an interview as a “data gathering technique involving verbal communication between the researcher and the subject”. Alshenqeeti (2014) explains it as a conversation between two people that provides ‘in-depth information’ about a certain topic or subject. An “interview is not simply concerned with collecting data about life; it is part of life itself, its human embeddedness is inescapable” (Cohen, Manion & Morrison, 2000, p. 267). Through an interview, a phenomenon can be interpreted based on the meanings

that the interviewees bring to it. Interviewing is beneficial in the sense that it gives the interviewees an opportunity to express their view of the world in which they live and how they regard the situation from their own point of view (Cohen et al. 2000). Interviews are advantageous to use because the researcher can clarify where the respondent does not understand. Alshenqeeti (2014) advises that when conducting interviews, researchers should not only be neutral, they should consider Richards' (2003) suggestion that the interviewers should seek the particular. In order to do this, the interviewer can establish an appropriate atmosphere, where interviewees can feel more ease and talk freely (Alshenqeeti, 2014). In this study, I ensured that conducive interview venues were selected according to the interviewees' choices. Interviewees were reminded that their anonymity would be maintained and that nobody would access the interview recordings apart from my supervisor and I.

Alshenqeeti (2014) outlines four types of interviews that are used commonly in social sciences: structured interview, open-ended (unstructured) interview, semi-structured interview, and focus group interview. This study employed the semi-structured interview. Semi-structured interviews are non-standardised and are often used in qualitative analysis (Kajornboon, 2005). The order of questions in a semi-structured interview can be changed depending on how participants respond (Corbetta, 2003). This type of interview is a more flexible version of the structured interview. It allows deep insight by providing the opportunity for the interviewer to probe and expand the interviewee's responses (Rubin & Rubin, 2005). When undertaking semi-structured interviews, researchers are advised to use main points/questions that would help to cover all relevant areas (Alshenqeeti, 2014). Although an interview is an advantageous data collection tool, De Santis (1980) argues that it remains a social interaction, where the behaviour of the interviewer may influence the answers of the respondent. That can provide biased results of the study and make them invalid (McLeod, 2014). This issue is addressed in the validity and trustworthiness section.

Semi-structured interviews helped me to collect data about teachers' own perceptions and understanding regarding their use of the visual and verbal modes. All the three teachers involved in this study were interviewed. The interviews were audio recorded for me to capture all the necessary details of their responses.

4.6. Piloting of data collection tools

According to Polit, Beck and Hungler (2001, p. 467) a pilot study is a “small scale version or trial-run in preparation for a major study”, which involves a pre-test or try-out of research instruments (Baker, 1994). A pilot study can be specific, pre-testing of research instruments including observations or interview schedules (Calitz, 2009). Practical problems in data collection instruments, sessions, and methodology can be detected in a pilot study (Hurst et al., 2015). That helps with self-correction between how instruments are designed and how they are implemented. A researcher is given an opportunity to revise the study materials and data collection procedures, ensuring that appropriate questions are being asked, and observation schedules are capturing sufficient data (Hurst et al, 2015). According to Morse et al. (2002), that will give the opportunity for improved reliability and accuracy in qualitative inquiry and analysis. That makes a pilot study one of the most effective techniques that can improve validity in qualitative data collection procedures (Foddy, 1998).

The pilot study involved testing of lesson observation schedules and the lesson observation analytical tool. The pilot study was done on two Physical Science lessons – a grade 8 lesson and a grade 9 lesson. This was done because the actual study was being conducted with teachers in the junior secondary phase. After the testing of lesson observations schedules and the analytical tools, the outline and organisation of the schedule was modified – for example, in the proposal of this study I outlined that I will give a description of visuals, but after the testing of instruments, I decided to screenshot the visuals and paste them in the analytical tool instead of simply describing them. I also piloted interview questions. Interview questions were tested on the two teachers that had their lessons observed for piloting purposes. Piloting of interview questions allowed for the correction of ambiguous questions and change of terminologies used – for example, the term ‘teacher talk’ is used instead of ‘verbal’, and ‘combination’ instead of ‘intersemiotic’. As proposed by Mathers et al. (1998) the pilot study helped me to refine the interview questions. The process enabled reflection on how the questions could most clearly be framed, and helped to identify some of the possible probing questions. The pilot study also helped in predicting the duration of the interviews and their transcription.

4.7. Data collection procedure

Initially, I planned the data collection process to be completed in a period of three months, but due to the 2018 Namibian schools' calendar being different from other years, the data collection process took approximately five months. In the Namibian school calendar for 2018, there was a two-week mid-break. After the mid-break there was only one week for teaching before the examinations for the first semester commenced, which was followed by a holiday. Some data sets were collected before the mid-break. During the one week between the mid-break and examinations, I could not collect any data because all three teachers involved in the study had indicated that they were busy revising what was covered in the whole of the first term and preparing learners for the examinations. The data collection was completed in the first month after the holiday. Within that time period, lesson observations and semi-structured interviews were done. The data collection procedure started with lesson observations followed by the interviews. As stated earlier, all three teachers were Junior Secondary Physical Science teachers (Grade 8 and 9). The times and dates for the sites that I visited were scheduled according to participants' availability, the school calendar, and my own time availability.

Twelve lessons overall were observed, four lessons per teacher. The lesson observation sheets (Appendix A) were informed by the themes that emerged from literature, as informed by SFL theory. Lesson observations involved video recording, audio recording and photographs with the consent of the participants. I used video recording to ensure that all visual and verbal communication by the teachers during the lessons was captured. Audio recording was used as a backup (in case sound quality of the video dropped at any point), and a camera enabled me to take quality pictures of the visual mode that could not be captured clearly by the video recording for the thesis.

Semi-structured interviews were conducted with the three teachers involved in the study. The interviews were conducted in English, some at schools and others at the respondents' choice of locations. This contributed to making the respondents comfortable, as suggested by Oltmann (2016). As suggested by Fox (2009) with regards to going to the respondent's choice of location, I inquired about the place and ensured that the room was free from interruptions and it could enable private interview. Interviewees were also involved in selecting the suitable time

of the day. The time was strategically chosen and agreed upon to ensure that respondents would not be interrupted (Fox, 2009). The interviews were audio recorded with the consent of the participants. Audio recordings of interviews allow for the natural flow of the conversation (Zhang & Wildemuth, 2006). It allowed me to engage in the conversation freely without worrying about note-taking. Furthermore, the audio-recording helped to provide detailed information of the interviews which could not be captured in the notes but were necessary for transcription in order to answer research questions one and two.

The interviews started with warm-up questions. Apart from helping in gaining confidence, warm-up questions helped the respondents to start thinking about the research interest (Campion, Pursell & Brown, 1988). After warm-up questions, participants were asked questions about issues related to the research questions. Participants were also afforded an opportunity to express what they felt was important and relevant to the study.

I used semi-structured interviews to collecting the data that was used to examined the Namibian Physical Science teachers' pedagogical practice by looking at how the teachers use verbal-visual intersemiotic complementarity in their lessons. Semi-structured interviews also collected data for examining possible correspondences between verbal-visual intersemiotic complementarity in classroom pedagogy and the number of years of science teaching experience.

4.8. Approach to data analysis

Data analysis is a process of organising data that allows for open discovery of emergent concepts (Bradley, Curry & Devers, 2007). In this study, qualitative data is analysed. Flick (2013, p. 5) defines qualitative data analysis as the “classification and interpretation of linguistic (or visual) material to make statements about implicit and explicit dimensions and structures of meaning-making in the material and what is represented in it”. Data analysis is vital in qualitative research. It does not matter how valuable data is, it is their analysis that

forms the outcome of the research (Flick, 2013). Bradley et al. (2007) propose that data analysis begins at the early stage of collecting data and continues through the study.

At some points, this qualitative study used graphs to present data collected from classroom observations. Scibilia (2015) reminds us that qualitative data may be counted and analysed using statistical methods. The use of graphic representation in qualitative studies is useful and serves numerous purposes at different stages of data analysis (Verdinelli & Scagnoli, 2013). Verdinelli and Scagnoli (2013) note that it helps to synthesise major theoretical concepts and their connections. This qualitative study used graphs to provide a multidimensional space to organise data and show connections between different pieces of relevant data (Dey, 1993). As proposed by Verdinelli and Scagnoli (2013), the use of graphs helps provide better insight and understanding of the data. It helped specifically in summarising and simplifying data attempting to answer research question 2, which was aimed at identifying the correspondences (if any) between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience. As argued by Yin (2011) graphs in this study also gave the possibility of seeing the meaning of the data in more ways than just textually.

One of the aims of analysing qualitative data is to describe a phenomenon in greater detail (Flick, 2013). Flick (2013) explains that the phenomenon can be the subjective experiences of a specific individual or group – for example, how teachers integrate the verbal and visual modes in science classrooms to communicate meaning. The analysis can also focus on comparing several issues on what individuals have in common or on the differences between them (Flick, 2013) – for example, examining if there are correspondences between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience (research question 2 of this study).

Data are analysed in two phases. The first phase involved the analysis of data collected from lesson observations using the analytical tools in Table 2 and Table 3. This is done by identifying the verbal-visual intersemiotic complementarity through the sense relations, and identifying how the teachers used each category of each sense relation respectively. Semi-structured interview data related to the research questions are also analysed in the first phase. I coded the

data from semi-structured interviews and classified the codes into themes. The second phase employed an inductive approach of identification of categories from the verbal-visual intersemiotic complementarity used by the teachers. The inductive approach involved moving from the particular or detailed data towards more general code and themes (Creswell, 2012). Inductive approach is a recognition of patterns within data resulting in themes and concepts (Cohen et al., 2011). In this study, those categories are referred to as the types of representations on which intersemiotic complementarity tends to focus. The second phase was not initially intended. I undertook it when I discovered that there were themes emerging from the codes.

Table 2: Analytical tool for analysing verbal-visual ideational intersemiotic complementarity

Visual resources/communication <i>Actual visual</i> (photographs/screenshots)	Verbal resource/communication <i>Actual verbal</i> (quotations)	Intersemiotic complementarity	Potential uses of verbal/visual resource (but not used)
		Repetition: identical meaning. Synonymy: the same or similar meaning. Antonymy: opposite meaning. Hyponymy: the relation between a general class of something and its sub-classes. Meronymy: the relation between the part and whole of something.	

As this was a qualitative study, qualitative data from lesson observations and interviews were analysed. Each of these will now be discussed.

4.8.1. Approaches to analysis of data collected from lesson observations

As stated in the theoretical framework section, metafunctional perspectives, namely the ideational, interpersonal and textual have the ability to explain and analyse several communicative phenomena (Hasan, 1993). Data collected from lesson observations in this study were analysed using one of these – the ideational metafunction. Ideational metafunctional perspective looks at how signs are interrelated to create a specific meaning (Silverman, 1993). Like language (verbal), visuals are representations of reality, experience and information, and in that sense, they can realise the ideational metafunction (Royce, 2007).

Analysis of verbal-visual intersemiotic complementarity in this study started with examining visual mode components. This is suggested by Royce (2007) with the reason that visual mode in science discourse is less complex compared to verbal in terms of degree and number of meanings that it can communicate. In addition, the verbal mode is viewed as a primary form of communication in most science classrooms and dominates the visual mode in modern education systems (Kress & van Leeuwen, 1996; Royce, 2007). As demonstrated by Royce (2007) it is likely for the verbal mode to carry far greater meaning which the visual mode cannot carry or address. Royce (2007) suggests that those meanings be ignored when focusing on intersemiotic complementarity because they do not semantically relate to the visual mode. Thus, it was useful to start with the analysis of the visual mode when analysing data collected from lesson observations in this study because visuals have fewer meanings. After the analysis of the visual mode, the verbal mode was analysed, looking at how the visual mode are semantically related to verbal modes.

After describing the features in the verbal mode and the visual mode, those features were analysed to examine how they complement each other intersemiotically. The aim was to identify how intersemiotic complementarity is realised (Royce, 2007), and to try to explain why the teachers have chosen (if they did) to use both the verbal and visual modes in the lesson.

The analytical tool (Table 2) used to analyse verbal-visual ideational intersemiotic complementarity is adapted from Royce (2007). Changes in the analytical tool are made for the tool to fit the purpose of this study. Royce’s tool gives a description of a picture and a summarised verbal text. In this study, the tool is designed to have a copy of the original picture of the visual mode instead of the description, and a quote of the verbal mode, instead of a summarised verbal text. The analytical tool used in this study also includes a section ‘potential uses of verbal/visual resource identified by the researcher (but not used)’, which is aimed at determining areas where teachers could have used visual mode or verbal mode but neglected to do so. The tool is used to explore the content of the verbal and visual modes, how they are used, and how they combine to communicate meaning, in handouts, posters and on the chalkboard

After the analysis of verbal-visual ideational intersemiotic complementarity was done using the analytical tool in Table 2, examples of sense relations’ categories, discussed in Chapter Three, were identified and presented using the analytical tool in Table 3.

Table 3: Analytical tool for intersemiotic sense relations categories

Sense Relations	Category	Example from lesson observations
Intersemiotic Repetition	Perfect match	
	Inflexion	
	Derivation	
	Homospatiality	
Intersemiotic Synonymy	Similarity	
	Exposition	
	Extension	
	Translation	
Intersemiotic Antonymy	Perfect opposite	
	Ideational divergence	
Intersemiotic Hyponymy	Visual more general	
	Verbal more general	
Intersemiotic Meronymy	Visual showing the whole	
	Verbal referring to the whole	

4.8.2. Approaches to analysis of data collected from semi-structured interviews

After gathering data from the interviews, I transcribed them (see Appendix B). Afterwards, the analysis of interviews was done. I started the analysis by reading through the transcribed interviews and coding them based on patterns in participants responses to the interview questions, looking at trends, similarities and contradictions of data collected from all three teachers. Coding is defined by Cope (2005, p. 280) as “a process of identifying and organizing themes in qualitative data”. I then classified the codes into themes. These categories were guided by my research questions.

4.9. Validity and trustworthiness

Validity and trustworthiness are concerned with how data collected by the researcher is reliable (Rolfe, 2006). According to Gunawan (2015) validity and trustworthiness is divided into: *credibility*, which is concerned with internal validity; *transferability*, which is concerned with external validity; *dependability*, which relates to reliability; and *confirmability*, “the degree to which the results could be confirmed or corroborated by others” (Lichtman, 2010, p. 228). Golafshani (2003) argues that if the validity and trustworthiness of a qualitative study can be maximised or tested, then results of the study may lead to generalisability. In agreement, Stenbacka (2001) adds that validity or trustworthiness consideration may contribute to qualitative research of high quality.

In order to increase validity and trustworthiness of this study, I used triangulation. Triangulation is the use of a variety of data collection tools to develop a comprehensive understanding of phenomena (Patton, 1999). The use of different data collection methods, compensate for their individual limitations and exploits their respective benefits (Shenton, 2004). Triangulation reduces the effect of researcher bias (Palincsar, 1998). In this study, lesson observation data are verified against interview data. In order to increase the credibility of interview data, member checking was used (Birt, Scott, Cavers, Campbell & Walter, 2016). In other words, after transcribing, the data was returned to respondents to check for accuracy and validation.

Furthermore, I piloted my data collection tools and analytical tools. Piloting is a process of finding out if the data collection tools will work in the ‘real world’ by trying it out first on a few people who have similar characteristics to those involved in the study (Collins, 2003). With the help of piloting, I made improvements on the tools before the actual data collection for answering the research questions. Piloting the data collection tools helped to identify possible problems which might have occurred if I had used the planned tools. It also helped me to make sure that all my participants understood the questions, and to make sure that respondents felt comfortable. Piloting of observation tools helped to assess the feasibility of the study, and to check if tools are realistic and workable.

Informed consent with the option to withdraw from the study at any point without prejudice is sought from participants. That helped to ensure that the data collection involved participants who are genuinely willing to participate and prepared to offer data freely (Shenton, 2004). It was highly likely for my presence in the classroom to influence the teachers’ classroom practice and the attention of learners. Even if the participants agree to the presence of the researcher, the fact that the researcher is observing them can make them behave differently from normal, and the researcher may never be sure that participants would do the same things if they were not being observed (Holly, 2000). For me to minimise the ‘Hawthorne Effect’ – the effect of being observed (Bertram & Christiansen, 2014), I set up my observation equipment in advance and carried out one lesson observation per teacher prior to the actual data collection, in order for learners and teachers to begin normalising my presence during the science lessons.

4.10. Ethical considerations

Ethics is a branch of philosophy that deals with the conduct and standard behaviour of people in relationships with each other (Kovacs, 1985). Research ethics is important, especially in research which involves humans and animals (Bertram & Christiansen, 2014). It requires that researchers should protect the dignity of their research participants and publish the information as researched (Fouka & Mantzourou, 2011).

There are various steps that are vital in research. It begins with research proposal writing and approval leading to the actual research study (Akaranga & Makau, 2016). The proposal and ethical clearance for this research was granted by the Education Higher Degrees Committee (EHDC) at Rhodes University (Appendix C).

Respect and dignity

I respected the rights for both teachers and learners who were directly or indirectly involved in the study. Data collected from teachers were published anonymously. Pseudonym names are used for direct quotes. The identities of the teachers were only made known to school principals where the permission to do the study was sought. I informed participants about their voluntary participation in the study, and about their freedom to withdraw at any time. I also stipulated that lessons would be video recorded for the purpose of observations, and interviews would be voice recorded.

Transparency and honesty

I clearly explained the aim of the research to the participants so that they knew what they were agreeing to. Participant teachers were requested to provide signed informed consent forms as evidence of their willingness to be part of the study (see Appendix D). Since lesson observation was conducted in classes where there were learners, parents of those learners were requested to sign informed consent letters giving permission for their children to be part of the class where the study was conducted (see Appendix E). Learners were also verbally requested for permission for me to carry out my study in their classrooms. The potential benefits of this study were shared with the participants.

Accountability and responsibility

In this study, ethical considerations were observed throughout the research process. During every step of the research process, I was accountable and responsible for negotiations to get

access to the schools by seeking permission from the Educational Director (see Appendix F) and school principals (see Appendix G) where the study took place. In my request, I clearly indicated the details of the research, its purpose and the participants who would be involved. I was fully accountable and responsible for all data collected. I kept all the data filed safely in order to avoid any loss or misplacement. I kept a backup of all my data in case if anything goes wrong.

Integrity, academic and professionalism

Data collected in this study were treated with sensitivity. Electronic data were stored in a device protected with a password. Non-electronic data were stored in a secure place to ensure that no one else gets access to the data apart from myself and my supervisor. I did not use the research for personal gain (apart from the degree that I will obtain using the data for this thesis), or to undermine science teachers in the region. This research presents data as they are, without favouring any interest. The research is my own work, and where I used the work of others, I acknowledge it according to the APA citation and Rhodes University Education Department Guidelines. In order to make sure that I have not unintentionally plagiarised, I have run my work through a text-matching software program, Turnitin (see Appendix H)

4.11. Chapter summary

In this Chapter, I described the methodological orientation, where I explained the qualitative case study as situated in the interpretive paradigm. The research goal, objectives and research questions are outlined. I also discussed the data collection techniques used to respond to my research questions, and how they were piloted. Data collection procedures, sampling and approach to data analysis were described. The issues of validity and trustworthiness were also discussed, before I ended the Chapter with ethical considerations.

CHAPTER FIVE: DATA PRESENTATION AND DISCUSSION

5.1. Introduction

As explained in Chapter 4, data was derived from lesson observations and semi-structured interviews. I observed three teachers' Physical Science (Junior Secondary) lessons. Interviews were then conducted with the three teachers. In this Chapter, I first provide the profiles of the participating teachers. I then present the data and its analyses before discussing the results in two phases. In the first phase, I summarise and discuss the results of the data collected from lesson observations and semi-structured interviews. The second phase focuses on analysis and discussion of the themes discussed in the first phase. In that phase, I look at the types of representations on which intersemiotic complementarity used by the teachers tends to focus. Thereafter, I focus on additional findings of the study.

5.2. Profiles of the teachers

The study focused on three Junior Secondary Physical Science teachers in the Oshana region, in the town of Ongwediva. Both the names of the teachers and the schools are not revealed in the study in order to maintain the anonymity and privacy promised in Chapter Four. Pseudonyms are used for each teacher and school. The first teacher (T1) is Mr Ananias, a male Physical Science teacher at Enhongelo Combined School. The school is located in Ompundja Circuit and it accommodates learners from Grade 1-10. Mr Ananias is a 'least experienced' teacher with about six months of Physical Science teaching experience. The second teacher (T2) is Mr Eino. Mr Eino is a male Physical Science teacher at Tulongeni Combined School. He has 7 years of Physical Science teaching experience which corresponds to my category of the intermediate experienced teacher. Tulongeni is a grade 1-10 school in Ompundja circuit. The third teacher (T3) is Ms Helena. Ms Helena is a female Physical Science and Life Science teacher at Odime Junior Secondary School. The school is located in Ompundja Circuit and it accommodates learners from grade 8-10. Ms Helena has 11 years of Physical Science teaching experience which corresponds to my category of the most experienced teacher. Table 4 shows a summary of the teachers' profiles.

Table 4: Profiles of participating teachers

Pseudonym Teacher's Name	Pseudonym School's name	Sex	Grade (s) taught (Physical Science)	Teacher's qualifications	Science teaching experience and teacher categorisation
Ananias (T1)	Enhongelo C S	M	Grade 8-10	Grade 12 B Ed	4 months (least experienced teacher)
Eino (T2)	Tulongeni C S	M	Grade 8-10	Grade 12 BETD ACE	7 years (intermediate experienced teacher)
Helena (T3)	Odime J S	F	Grade 9	Grade 12 BETD ACE	11 years (most experienced teacher)

Key:

B Ed – Bachelor of Education

BETD – Basic Education Teacher Diploma

ACE – Advanced Certificate in Education

5.3. Classroom observation results and semi-structured interview results (Phase 1)

In order to answer research questions 1 and 2, I carried out four lesson observations each for three teachers. I further carried out individual semi-structured interviews with the three participant teachers. The semi-structured interviews also aimed at answering question 1 and research question 2. Research question 1 aimed at identifying how Namibian Physical Science teachers use verbal-visual intersemiotic complementarity in their lessons. Research question 2 aimed at identifying the correspondences (if any) between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience.

In this section, I present a summary and discuss the data collected from lesson observations and semi-structured interviews. First, I present the processes involved in the lesson

preparation/planning. I then provide an overview of teachers' lessons. The section further explores how each intersemiotic sense relation is used by the teachers. Finally, I consider how the teachers use verbal-visual intersemiotic complementarity

5.3.1. The processes involved in lesson preparation/planning

In this section I present and discuss the participating teachers' perceptions of what is involved in lesson planning. I also look at the participating teachers' consideration of the verbal mode, visual mode and verbal-visual intersemiotic complementarity.

5.3.1.1. Teachers' perceptions about the processes involved in lesson planning

Table 5 shows teachers' perceptions about the process involved in lesson preparation/planning, based on the interview question which focused on this

Table 5: Teachers' perceptions about the process involved in lesson preparation/planning

Question	Similarity (themes)	Differences (themes)
2. Can you describe for me the process involved in the preparation of a lesson, from the beginning?	• Teaching and learning activities (T2, T3). • Deciding about the inclusion of practical activities (T2, T3).	• Pre-reading (T1). • Getting ready for learners' questions (T1). • Writing a lesson plan (T1). • Considering the grade (T2). • Identifying learners' prior knowledge (T2). • Thinking about how to introduce the lesson (T2). • Teaching aids (T2). • Basic competences (T3).

The teachers' responses revealed that the two experienced teachers (Eino and Helena) share an understanding that lesson preparation/planning needs to include teaching and learning

activities. They also highlighted that during the lesson preparation/planning, teachers need to decide whether they are going to include practical activities in their lessons or not. According to the social constructivism theory, practical work needs to be an integral part of the learning sequence because it provides opportunities for more open-ended investigations which better challenge students' thinking (Skamp, 1998).

The teachers' responses also indicated different perceptions on what should be included in the process of the lesson preparation/planning. Ananias, the least experienced teacher has the view that lesson preparation starts with pre-reading about the topic. He said: *"you pre-read, you take the topic that you are going to teach tomorrow, you read through it so that you understand everything to be ready for learners' questions tomorrow"*. He indicated that after the pre-reading he writes a lesson plan. This agrees with Evans, Hawksley, Holland and Caillau (2008) who show that despite having a teaching qualification, novice teachers' knowledge prior to teaching is not enough to enable them to teach with confidence. Evans and colleagues add that there are aspects of the syllabus in which new teachers lack subject knowledge (Evans et al., 2008). Pre-reading can help a new teacher to have deeper knowledge of the topic and subject in general in order for their teaching to be effective (Coe, Aloisi, Higgins & Major, 2014). Eino and Helena did not indicate that they pre-read during the lesson preparation, but during their lesson presentations they demonstrated a deep knowledge of Physical Science as evidenced by Appendix I and Appendix J. This could be because they have taught Physical Science for a number of years compared to Ananias.

Eino has an understanding that teachers need to consider the prior knowledge of the learners during lesson preparation. He views learners' prior knowledge as a starting point when preparing teaching and learning activities. He said:

"If you are going to teach the grade 9s or even the grade 10s, you know already that these people have covered...what they have covered, their prior knowledge. Now you start building your lesson based on the prior knowledge of [what] the learners have already".

Eino further indicated that knowing learners' prior knowledge gives the teacher ideas of how to introduce the lesson, before designing teaching and learning activities. Prior knowledge is emphasised in the Namibian curriculum. The curriculum advocates that "learning in school must constantly relate to, involve, and extend the learners' prior knowledge and experience" (Namibia. MoE, 2009, p. 39). This is supported by social constructivists who believes that learning requires reflection of prior and new knowledge to extends students learning beyond the content presented to them (Giesen, 2009). Furthermore, the curriculum proposes that the point of departure in lesson preparation should always be what the learners already know and can do (Namibia. MoE, 2009). Although Ananias and Helena did not indicate that they consider prior knowledge during their lesson preparations, their lesson presentation activities showed that they do consider the prior knowledge of learners. For example, before she starts a new lesson, Helena always asked questions about the previous lessons, or what learners knew about the topic from the previous grades or other subjects. This strategy is supported by Yuksel (2012) who identified it as *reflection or recording strategy*.

Helena thinks that lesson preparation starts with understanding the basic competences (specific objectives). She said: "*Okay, the first thing that I look at is the basic competences, what do I expect learners to know*". Although only Helena indicated that she first focuses on what learners are expected to know, Ananias' and Eino's lesson presentations showed that they were familiar with the specific objectives of each lesson they presented. This is supported by Milkova (2012) who advises that before teachers plan their lessons, they first need to identify the basic competences and learning objectives, in order to design appropriate learning activities. The Namibian National Curriculum for Basic Education also advocates this. The curriculum indicates that the syllabi describe the competencies that learners should attain in each subject (Namibia. MoE, 2009).

Although the national curriculum states that learning aids and support materials like visual aids should be included in the lesson plan (Namibia. MoE, 2009), none of the teachers indicated that the visual mode is part of their lesson preparation/planning. While Eino indicated that he considers teaching aids during the lesson preparation, he did not specify details related to the visual mode.

5.3.1.2. Teachers' decisions about the use of verbal-visual intersemiotic complementarity

Table 6 shows the teachers' decisions towards the use of verbal-visual intersemiotic complementarity in Physical Science lessons.

Table 6: Teachers' decisions towards the use of verbal-visual intersemiotic complementarity

Question	Similarity (themes)	Differences (themes)
9. Did you come across a general policy (guide line) on the use of verbal and visuals integrating in the classroom? If so, what is it?	• Had never seen a policy on use of verbal-visual intersemiotic complementarity (T1, T2, T3).	• Learned how to use verbal and visuals during university study (T1).
10. How do you decide whether to use certain visuals, or a combination of verbal language and visuals?		• Learners' understanding (T1). • Syllabus (T2). • Experience (T2). • Learners' interest (seeing) (T3).
11. In deciding on what will be your verbal explanation in relation to the visuals, what guidelines do you use?	Syllabus (T2, T3)	• Subject knowledge (T2). • Experience (T2).
12. Do you decide first on verbal communication and then try to fit in visuals around it? Or is your verbal communication arranged around the visuals?	• Verbal explanation (T1, T2).	• Visuals (T3).

Different teaching-learning theories and methods support the concept of using verbal-visual intersemiotic complementarity. Some theories – for example, SFL detail guidelines for using verbal-visual intersemiotic complementarity in science classrooms and their development of scientific knowledge and skills. The discussion in this section is structured according to the following categories:

- Policy/guidelines on the use of verbal-visual intersemiotic complementarity
- What factors contribute to the teachers' decision to use the visual mode or verbal-visual intersemiotic complementarity?
- What factors contribute to the teachers, decision to use the verbal mode in relation to visual mode?
- Is the verbal mode or visual mode considered first when they are integrated?

1. Policy/guidelines on the use of verbal-visual intersemiotic complementarity

All the participating teachers indicated that they have never seen a policy or guideline on how to integrate the verbal and visual modes in science classrooms. It is problematic to the verbal-visual intersemiotic complementarity in Physical Science lessons if there is no a general guide helping teachers. Shabiralyani et al. (2015) point out that guidelines on the use of verbal-visual intersemiotic complementarity can give teachers insights into the use of verbal-visual intersemiotic complementarity in science classrooms. It is also argued that such guidelines are imperative to redirect teachers' opinions, perceptions, experiences, failures and success while using the verbal and visual modes, especially for novice teachers (Shabiralyani et al., 2015; Al Mamun, 2014). If teachers are not provided with guidelines on how they can employ verbal-visual intersemiotic complementarity, they might not understand its importance in science classrooms, or even consider it.

2. What factors contribute to the teachers' decision to use the visual mode or verbal-visual intersemiotic complementarity?

Due to the lack of a general policy or guidelines on how to use verbal-visual intersemiotic complementarity in Namibian schools, the teachers involved in this study have different views on what guides them when integrating the verbal and visual modes. Ananias indicated that he is guided by learners' understanding, he said:

“If I see that learners understand what I am saying just from the talking explanation, sometimes I leave out the visuals. But if I see that learners do not understand very well, I will take a visual aid to explain more. My decision is influenced by learners’ understanding. If they don’t understand, I use visuals. If they understand, I can ignore the visuals”.

Ananias’ views are supported by Shabiralyani and colleagues who claim that “visual aids are tools that help to make an issue or lesson clearer or easier to understand and know” (Shabiralyani et al., 2015, p. 226).

In his responses, Eino stated that he is guided by the syllabus, his teaching experience and his creativity. He explained:

“The syllabus becomes the driving tool that will tell you what those children need to understand or need to know at the end of the day. Now, once you understand what children need to know at end of the day, that is when you think out of the box, and think of what you should bring to class, in terms of preparation. The preparation is telling you what you should bring to class in terms of visuals. There is no policy that tells you how to integrate the two, that is depends on the creativity of the teacher.”

His views that a syllabus is a starting point is supported in the Physical Science Syllabus for Grades 8 & 9 which indicates that the syllabus describes the intended learning outcomes for Physical Science (Namibia. MoEAC, 2015). In the syllabus, the intended learning outcomes are detailed and specified in specific objectives.

Helena is guided by her experience with learners and by the learners' interests. She said:

"I have realised that learners prefer something that they can see with their eyes instead of what they hear, or rather than theory. So, I try by all means to find either a poster or to come up with a diagram or may be [check] in the textbook at least [to find a visual] related to the topic that I am busy with".

Clarke, Flaherty and Yankey (2006) agree that learners prefer to be taught through pictures, diagrams, flowcharts and films. Yet, most classroom instruction still present content primarily through verbal mode (Clarke et al., 2006). Although learners' interest may not be a guideline, it motivates Helena to employ the visual mode.

3. What factors contribute to the teachers' deciding to use the verbal mode in relation to visual mode?

Ananias, the least experienced teacher could not specify what influences his decision to use the verbal mode in relation to the visual mode. His inability to explain what influences him is likely to hinder his effective integration of the verbal mode with visual mode. This is probably a challenge common to other least experienced science teachers in Namibia.

Eino and Helena share a similar understanding on what influences them when deciding to use the verbal mode in relation to visual mode. They indicated that they are influenced by the syllabus. Eino said: *"the syllabus is what drives us"*. Helena stated:

"I am guided by the syllabus. The syllabus dictates what and how I should explain to learners".

As discussed in the previous section, the syllabus in the Namibian education system is the guiding document on the intended learning for each subject. However, the syllabus did not specify how teachers should use the verbal mode in relation to the visual mode or vice versa.

Eino further indicated that he is also influenced by his subject knowledge and teaching experience. He said: *“Subject knowledge plays a major role there, as an experienced teacher, I know already how I will present my lesson from experience”*. He further stated that after he identifies what learners are expected to know, he can already tell which visual is suitable to integrate with what he is going to say verbally. So, the teachers involved in this study believe that teaching experience places teachers in a good position to complement the verbal mode with the visual mode. However, the results from the lesson observations discussed in section 5.3.4. contradict this.

4. Is the verbal mode or visual mode considered first when they are integrated?

Ananias and Eino indicated that they choose details around the verbal mode first, and then try to integrate the visual mode around it. Ananias states that he begins with the verbal mode, *“then from there I can decide on the type of visuals that contain all the competences that I am going to teach that day”*. Eino said: *“once you now understand your verbal explanation, that is when you bring in the visuals”*. On the other hand, Helena indicated that she chooses visual mode first. She said: *“first the visual, and then I can come up with a question like, what do you see in the diagram?”*.

Ananias and Eino, who indicated that they chose the verbal mode first, used verbal-visual intersemiotic complementarity more often than Helena who said she chooses the visual mode first.

5.3.2. How the intersemiotic sense relations were used by the teachers

All three teachers used verbal-visual intersemiotic complementarity in their lessons, which were identified using intersemiotic sense relations. In the interviews, the teachers were asked to give practical examples on how they could use each intersemiotic sense relation in Physical Science lessons. In this section, I focus on how the intersemiotic complementarity was realised through each sense relation. I also look at the teachers' ideas about how they can use each sense relation in their Physical Science lessons.

As discussed in the theoretical and analytical framework Chapter (Chapter 3), the use of intersemiotic sense relations makes multimodal science discourse verbally-visually coherent. All the three teachers used all the five sense relations in their lessons. That is an indication that there is some level of cohesion between the teachers' verbal and visual modes in their Physical Science lessons. The instances of intersemiotic complementarity that occurred in the teachers' lessons varied. Some teachers used some sense relations more often than others.

In the following sub-sections, I present how intersemiotic repetition, intersemiotic synonymy, intersemiotic antonymy, intersemiotic hyponymy, and intersemiotic meronymy were used by the teachers in Physical Science lessons. I will also discuss teachers' perceptions on how they would use each intersemiotic sense relation in their Physical Science lessons.

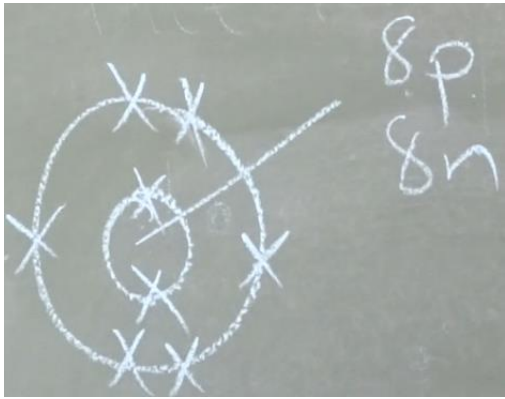
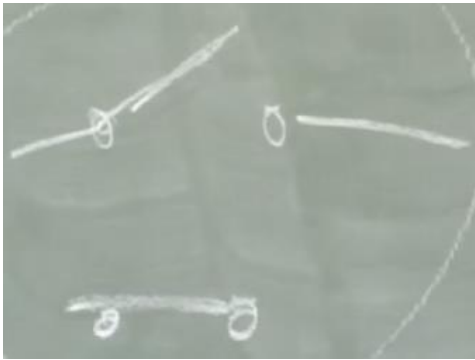
5.3.2.1. *Intersemiotic repetition*

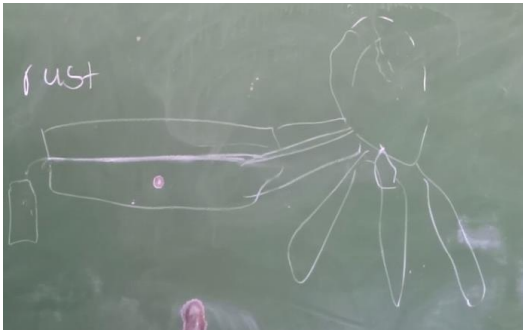
One of the examples of intersemiotic repetition of a perfect match was identified in the second lesson by Ananias. In that lesson, Ananias used a visual showing an atomic structure of an oxygen atom having *eight electrons*, and a lexical item in the verbal mode referring to *eight electrons* (see Table 7). The visual mode and the verbal mode in that case were exactly the same, with the same grammatical number – they were all in plural number. A repetition of items that are morphologically distinct due to inflexion was observed in the Eino's second lesson, where he used a visual showing an open switch and a closed switch, which were glossed

as *switches*. A lexical item to it in the Eino's verbal mode was *switch* (see Table 7). That is an example of morphological distinct due to inflexion because the inflectional morpheme is added to *switch* to modify the grammatical number (Altakhaineh, 2014). An example of morphological distinction due to derivation was observed in Helena's forth lessons, where she used a visual showing a *condenser*, and a lexical item in her verbal mode referring to *condensation* (see Table 7). In that example, *condenser* and *condensation* are morphologically distinct due to derivation because those words are formed on the basis of the existing word (Dixon, 2014). Condensation and condenser are from the root word condense.

Table 7 shows examples of each category of intersemiotic repetition observed in the lessons taught by the teachers. Only one example is given for each category.

Table 7: Intersemiotic repetition observed in the teachers' lessons

Sense relations	Category	Example from lesson observations	Teacher
Intersemiotic repetition	Perfect match	Verbal: "Eight electrons" Visual: Eight electrons 	T1
	Inflexion	Verbal: "Switch" Visual: Two switches 	T2

	Derivation	Verbal: “Condensation” Visual: Condenser 	T3
	Homospatiality	No homospatiality found	

Intersemiotic repetition was the most-used sense relation by Helena (33%), and the second-most used sense relation by Ananias (29%) and Eino (20%). The teachers used three of the four categories of intersemiotic repetition identified in Chapter 3. The categories that the teachers used were: perfect match, morphologically distinct due to inflexion, and morphological distinct due to derivation. Intersemiotic repetition through homospatiality was not identified in any of the teachers’ lessons.

Table 8 shows the teachers’ responses to where and how they can use intersemiotic repetition in their Physical Science lessons, apart from the instances observed in their lessons.

Table 8: Teachers’ responses to where and how they can use intersemiotic repetition in Physical Science lessons.

Question	Similarity (themes)	Differences (themes)
13.1. Give me examples where and how you can use Repetition (the verbal mode repeating what is in the visual mode or vice versa).	• Matter (T1, T3).	• Bonding (T1). • Measuring of mass (T2). • Drawing atomic structures (T3).

Responses from the teachers revealed that all the three teachers have ideas about how they can use intersemiotic repetition in terms of verbal-visual intersemiotic complementarity in Physical Science lessons. None of the teachers included instances of items which are morphologically distinct due to inflexion or derivation, in their examples. Their intersemiotic repetition involved the repetition of a lexical item which expresses exact meaning represented in the verbal and visual modes (Royce, 1999), what I termed ‘perfect match’.

The sense relation of repetition, as discussed in Chapter Three, would be an appropriate intersemiotic sense relation to adapt and use for the reiteration of the meaning across the verbal and visual modes in science classrooms.

5.3.2.2. *Intersemiotic synonymy*

Intersemiotic synonym similarity is the most common intersemiotic synonymy in the teachers’ lessons. Eino used it in his first lesson, where the visual mode showing *zero* on a number line was referred to the verbal mode saying *neutral* (Table 9). That is an example of intersemiotic synonymy through similarity because when dealing with charges in science, zero and neutral refer to the same thing.

Some of the synonymous items used by Ananias, Eino and Helena included exposition. There were situations where the teachers re-expressed the meaning of the visual mode in verbal mode and vice versa. In Ananias’ second lesson, a visual showing *atoms which look alike* concurred synonymously with the verbal mode: *atoms of the same kind* (see Table 9). Although *look alike* and *same kind* may not be similar, they are expressing the same meaning in this context. That makes the verbal and visual expressions synonymous.

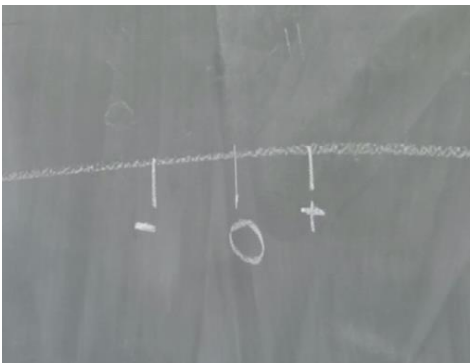
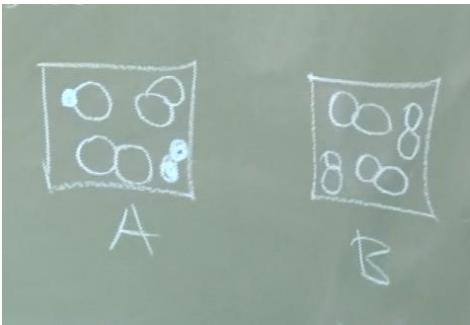
All the three teachers used ‘extension through similarities’ – instances where the visual mode extends the meaning of the verbal mode or vice versa (van Leeuwen, 2005). An example of extension through similarities given in Table 9 is from one of Ananias’ third lesson. Ananias

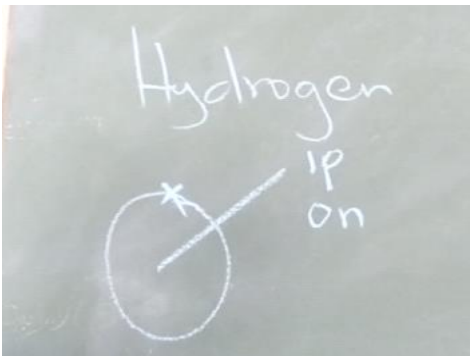
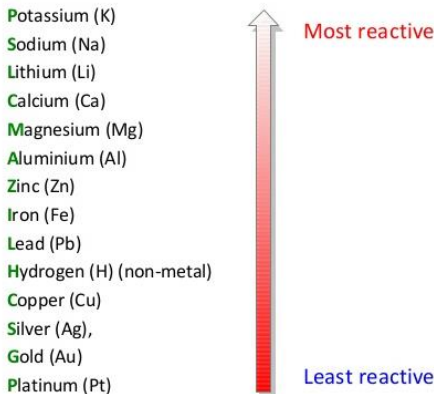
used a visual showing an *atomic structure of hydrogen having one shell*, that was extended by a verbal mode saying *hydrogen is in period one*.

The teachers also used intersemiotic translation. As discussed in Chapter 4, intersemiotic translation involves the translation between language into non-verbal system of symbols. Intersemiotic translation is observed in Helena's second lesson. Helena used a lexical item in her verbal mode referring to *the reactivity series*, which was translated into a visual showing an *arrow indicating the reactivity series of several metals* (see Table 9).

Table 9 shows examples of each category of intersemiotic synonymy observed in the lessons of the teachers. Only one example is given for each category.

Table 9: Intersemiotic synonymy observed in the teachers' lessons

Sense relation	Category	Example from lesson observation	Teacher
Intersemiotic synonymy	Similarity	Verbal: "Neutral". Visual: Zero. 	T2
	Exposition	Verbal: "Atoms of the same kind". Visual: Atoms which look alike. 	T1

	Extension	Verbal: “Hydrogen is in period one”. Visual: Hydrogen atom having one shell. 	T1
	Translation	Verbal: “The reactivity series”. Visual: Arrow indicating reactivity series. 	T3

All the three teachers used intersemiotic synonymy and it was the third-most used sense relation by Ananias (21%), and the second-most used sense relation by Eino (22%). Intersemiotic synonymy was the second-most used sense relation by Helena (22%). All the four categories of intersemiotic synonymy discussed in Chapter 3 (similarity, exposition, extension through similarity and translation) were used by the teachers in their Physical Science lessons.

Table 10 shows teachers' responses to where and how they can use intersemiotic synonymy in their Physical Science lessons, apart from the instances observed in their lessons.

Table 10: Teachers' responses to where and how they can use intersemiotic synonymy in Physical Science lessons

Question	Similarity (themes)	Differences (themes)
13.2. Give me examples where and how you can use synonymous items in the intersemiotic complementarity of verbal and visual modes (the verbal mode referring a similar meaning in the visual mode).	• Matter (T1, T3). • Bonding (T1, T3).	• Resistance (T2).

Table 10 shows that all the three teachers were able to give examples for the use of intersemiotic synonymy in their Physical Science lessons. As with repetition, their responses revealed that Ananias and Helena indicated that they can use intersemiotic synonymy when explaining matter. Eino indicated that he can use it in explaining electricity.

Ananias said when teaching ionic bonding, teachers can use a visual *“having something written electrovalent, but when you are referring to learners you are saying ionic bonding”*. In this example, electrovalent and ionic bonding are different words, but they mean the same thing. This kind of synonymy relation is what I termed ‘similarity’. Helena indicated that:

“When you are drawing, for example sodium with eleven electrons, the first shell will hold two electrons, the second will hold eight and the last one, the third shell will hold one electron. So, learners will see that this one electron on the outer shell is equal to the group number”.

In Helena's example, because the third shell has one electron, the teacher can verbally say sodium is in group one. This is an example of what Torresi (2008) described as 'translation'. As discussed in Chapter 3, the verbal mode in this case will be an abstract phenomenon if it is isolated from the visual mode. In other words, in the absence of a visual, learners may not understand why sodium is in group one.

Eino stated that:

"That can be applied when we are talking about the issue of resistors. If you want to calculate for example resistance in parallel, you can have a visual [mode] showing resistors connected across to each other, verbally you can say resistors are connected in branches".

He also gives another example:

"You can also have a visual [mode] showing bulbs, but you can verbally refer to resistors, because bulbs can also stand as resistors because they contain their own resistance. So, verbally you are saying they are resistors, but what learners are seeing are bulbs. So, bulbs and resistors can go hand in hand".

The first example given by Eino is what Martinec and Salway (2005) described as 'exposition'. The verbal mode and the visual mode are of the same level of generality because 'across to each other' and 'branches' are synonyms. That makes the verbal and visual modes synonyms. Eino's second example of synonymy falls in the category of Van Leeuwen's (2005) term 'extension'. The meaning of the verbal mode extended the meaning of the visual mode. The communication strategy used in this example promotes continuous relations between the resistors (verbal mode) and the light bulbs (visual mode) (Maier et al. 2007).

5.3.2.3. Intersemiotic antonymy

The teachers used both categories of intersemiotic antonymy identified Chapter 3. The categories are ‘perfect opposite’ and ‘ideational divergence’. In his first lesson, Ananias used intersemiotic antonymy, where the visual mode showed an *increase in the number of resistors*, the verbal mode was: *the total resistance decreases*. Intersemiotic antonymy was also observed in Eino’s third lesson, where he used a visual showing a circuit diagram having *arrows pointing from the positive terminal to the negative terminal*. The verbal mode was: *the charges move from negative to positive* (see Table 11). An example of intersemiotic antonymy from Helena’s lessons includes a situation where she used a visual showing a *decrease of the intensity of red colour as the row goes up* and a verbal saying the *reactivity series increase as the arrow goes up* (second lesson). All these examples are of perfect opposite. What is shown in the visual mode is directly opposite to what is said in the verbal mode.

Intersemiotic antonymy through ideational divergence is also observed in several lessons. An example of ideational divergence was observed in Ananias’ second lesson, where he used the visual mode showing *substances made up of different kinds of atoms*, and the verbal mode saying *an element is made of one kind of atom* (see Table 11). Divergence was also observed in Helena’s first lesson, where a statement: *metals and non-metals in the periodic table are separated by a zig zag line* was made in the presence of a visual showing *metals in a periodic table which are not separated by a zig zag line*. All these examples are of intersemiotic antonymy through ideational divergence because the visual mode and verbal mode have contradictory messages (Vorvilas, 2014).

Intersemiotic antonymy is the least used sense relation by the teachers in this study. Generally, there are few opposite words or meanings in science that can contribute to the construction of knowledge. In other disciplines, such as the languages, antonymy covers a wide range of binary contrast pairs which express the opposite of each other (Kostić, 2017). Some contrast pairs that express opposite word class that share crucial semantic properties (Kostić, 2017) in science are shown in Table 11.

Table 11 shows examples of each category of intersemiotic antonymy observed in the lessons of the teachers. Only one example is given for each category in the Table.

Table 11: Intersemiotic antonymy observed in the teachers' lessons

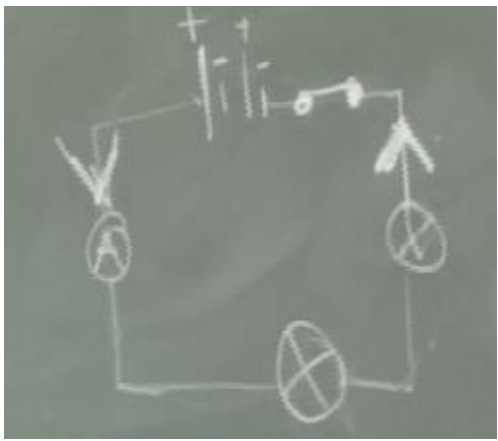
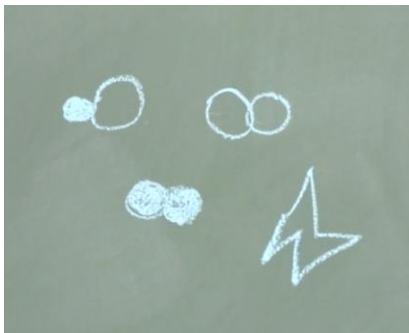
Sense relation	Category	Example from lesson observation	Teacher
Intersemiotic Antonymy	Perfect opposite	Verbal: "the charges move from negative to positive". Visual: arrows pointing from the positive terminal to the negative terminal. 	T2
	Ideational divergence	Verbal: "an element is made of one kind of atom". Visual: substances made up of different kinds of atoms. 	T1

Table 12 shows teachers' responses to where and how they can use intersemiotic antonymy in their Physical Science lessons, apart from the instances observed in their lessons.

Table 12: Teachers’ responses on where and how they can use intersemiotic antonymy in Physical Science lessons.

Question	Similarity (themes)	Differences (themes)
13.3. Give me examples of where and how you can use Antonymy – opposite words (verbal saying something opposite to visual).	• Resistance (T2, T3).	• Changes of state (T1).

As shown in Table 12, Eino and Helena’s responses revealed that they can use intersemiotic antonymy when discussing resistance in the topic electricity, for example, when dealing with resistance. Eino indicated that when teaching resistance, *“you can have a picture of conductors having different dimensions (diameter), drawn [in their order] from the smallest to the largest.* He added that verbally, a teacher can explain that *“when the diameter of a conductor increases, the resistance will decrease”*. This is an example of what I termed ‘perfect opposite’. The meaning of the verbal mode and the visual mode is a direct opposition relation. Helena also indicated that antonymy can be used when teaching resistance, she said: *“The higher the resistance the lower the voltage (current)”*. She could not give practical examples on how she can use the verbal and visual modes to communicate this message to learners.

Ananias indicated that he can use intersemiotic antonymy in the topic Matter, when teaching about changes of states. He indicated that: *“You can have a diagram whereby you are having an arrow pointing from solid to liquid, but in your explanation, you can include moving back from liquid to solid”*. In the example given here, what is said in the verbal mode is contradictory to what is shown in the visual mode. In terms of knowledge production, the example given by Ananias can help learners to understand that the change of states is not a one-way route. It is reversible.

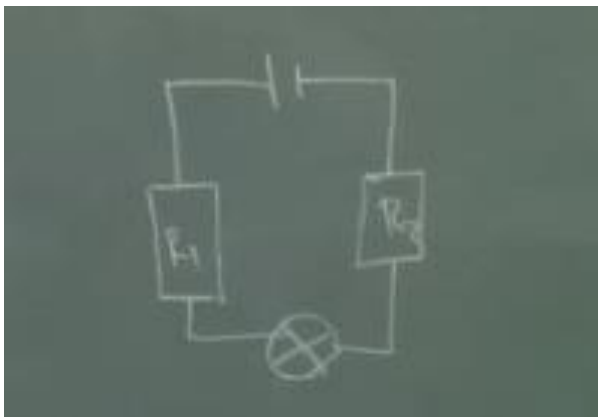
The intersemiotic antonymy discussed in this section has a potential consequence of positive impact, negative impact or no impact on learners’ acquisition of scientific knowledge. Intersemiotic antonymy that may have positive impact on learners’ acquisition of scientific knowledge are the ones that can help learners to differentiate opposite concepts – for example,

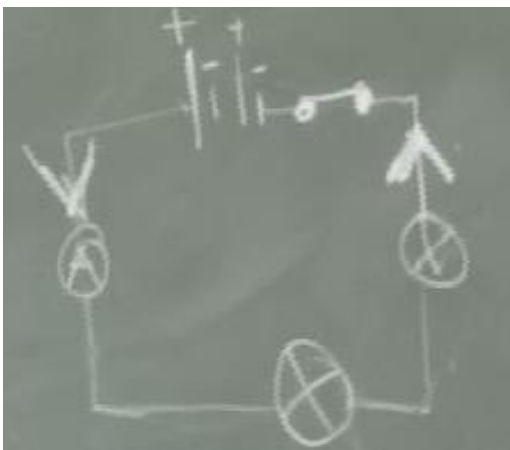
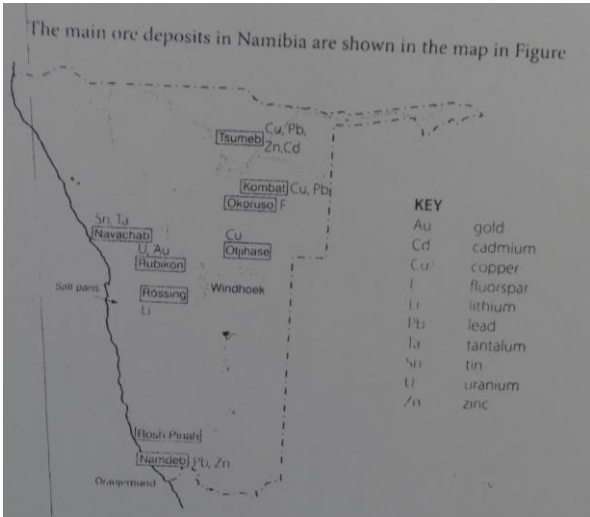
parallel and series circuits. There are also some opposition items which learners can understand better if they are learned in parallel – for example, increase of the speed and decrease of the time taken. Intersemiotic antonymy that may lead to negative impact on learners’ acquisition of scientific knowledge includes the use of synonyms items that learners can easily misinterpret. In addition, if a teacher keeps on discussing a concept which is not the one shown in a visual displayed in the classroom it can also lead to negative impact. The intersemiotic antonymy with no impact on learners’ acquisition of scientific knowledge are the one that may not have an influence on the knowledge acquisition. What is in opposition is not part of what is being learned. The next discussion looks at possible impacts of intersemiotic antonymy on learners’ acquisition of scientific knowledge, observed in the teachers’ lessons.

Possible impacts of intersemiotic antonymy on learners’ learning

Apart from helping learners to understand a situation better, intersemiotic antonymy can also lead to misunderstanding and confusion (Gjergo & Delija, 2014). Examples of how teachers used intersemiotic antonymy with different impacts in their Physical Science lessons are shown in Table 13.

Table 13: The impact of the intersemiotic antonymy used by the teachers

Impact	Visual mode	Verbal mode	Teacher
Positive Impact	Series connection. 	“Now I want us to draw another one, but this time around, it is a parallel connection”	T1

Negative Impact	Arrows pointing from positive to negative. 	“Charges move from negative to positive”.	T2
No Impact	Mineral written in key on the right side in the map. 	“The names of the metals are on the left side in the paper”	T3

In Table 13, the first example has a positive impact on the acquisition of knowledge. It is informing learners that the series connection is not the only connection, there is another type of connection, the parallel connection. This intersemiotic antonymy can be a good way of reminding learners about what was learned before, or introducing learners to what they will learn next. The second example in Table 13 is of a negative impact of intersemiotic antonymy. The direction of the arrows and the verbal explanation of the teacher are not corresponding. Although the teacher is saying charges move from negative to positive, some learners might grasp what is shown in the visual mode. In that case, intersemiotic complementarity is not serving its purpose. It is not helping learners to obtain the knowledge that they may otherwise not get from verbal explanation alone as proposed by Patrick, Carter and Wiebe (2005).

As stated earlier in this section, some intersemiotic antonymy do not have any impact on the learners' learning. In the last example given in Table 13, the teacher said that the minerals were on the left side, but in the map, minerals are listed on the right side. It does not matter if the teacher mentioned the correct position of the minerals in the map or not. The position of the minerals in the map has nothing to do with the expected learning outcome. Figure 5 shows the numbers of possible impacts of the intersemiotic antonymy used by the teachers.

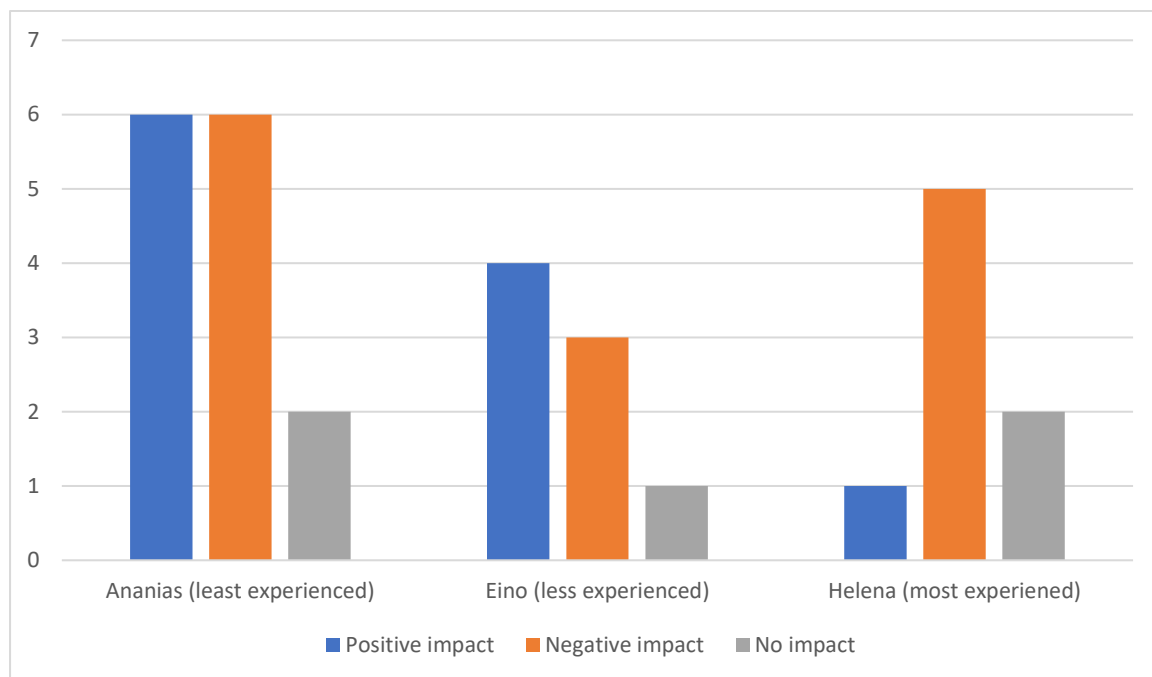


Figure 5: The numbers possible impacts of the intersemiotic antonymy used by the teachers

Figure 5 shows an unexpected result, the most experienced teacher who was expected to use more intersemiotic antonymy with positive impact, used intersemiotic antonymy with negative impact the most. The intermediate experienced teacher used intersemiotic antonymy with positive and negative impact equally. The least experienced teacher used intersemiotic antonymy with positive impact more compared to negative impact, with only a slight difference. All the teachers used intersemiotic antonymy with no impact, fewer times compared to other impacts. The use of intersemiotic antonymy in the way that negatively impacts on learning is worrisome. Instead of the intersemiotic complementarity to enhance learning, it constrains it.

The results revealed that teachers' use of intersemiotic antonymy in terms of positive and negative impact does not improve as the teachers get more experienced. This can be due to the lack of understanding of how the verbal and visual modes can be integrated semantically to produce a coherent text with positive impact to learners' learning. Due to the small sample for this case study, this finding may not be generalised.

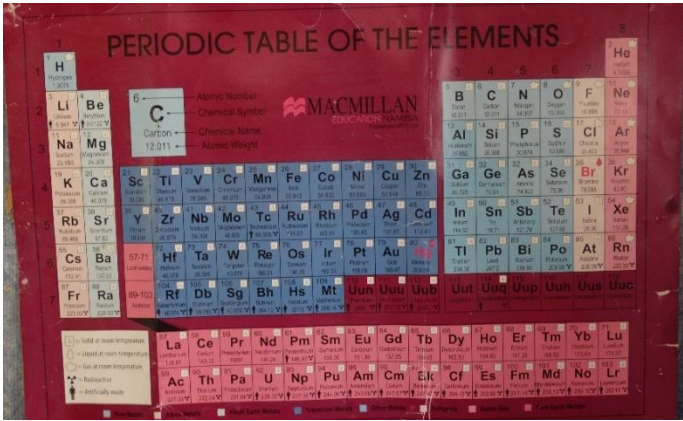
5.3.2.4. Intersemiotic hyponymy

The use of intersemiotic hyponymy in Ananias' lessons includes a situation in his second lesson where he used a visual showing *period one elements in a periodic table*, and a verbal statement referring to *helium* (see Table 14). In this example, the visual mode is the main class and the verbal mode is the subclass. In Helena's fourth lesson, she used a visual showing *the preparation of 'ombike'* (Oshiwambo traditional gin) and a verbal statement referring to *ombike of eendunga* (palm fruit gin). The visual mode in that example is the general class and the verbal mode is the sub-class.

There are also situations where the verbal mode is the general class and the visual mode is the subclass. For example, in Eino's second lesson, the visual mode was showing *a symbol of a connecting wire*, and the verbal mode was referring to *circuit symbols* (see Table 14).

Table 14 shows examples of each category of intersemiotic hyponymy observed in the lessons of the three teachers. Only one example is given for each category in the Table.

Table 14: Intersemiotic hyponymy observed in the teachers’ lessons

Sense Relations	Category	Example from lesson observations	Teacher
Intersemiotic Hyponymy	Main class: visual, sub- class: verbal	Verbal: “Helium”. Visual: Period one elements in the periodic table. 	T1
	Main class: verbal, sub- class: visual	Verbal: “Circuit symbols”. Visual: Symbol of a connecting wire. 	T2

The examples of intersemiotic hyponymy discussed in this section are tested with the concept of C1 and C2, described by Zhan and Wang (2015), discussed in Chapter 3. In the example of intersemiotic hyponymy from Ananias’ lesson, the hyponymy relation ISA (C1, C2), is evident in ISA (helium, period one element) because helium is one of the period one elements. In the example from Helena’s lesson it will be ISA (*ombike* for *eendunga*, *ombike*). That tells us that *ombike* for *eendunga* is one of the kinds of ombike. If we apply the concept of C1 and C2 to the intersemiotic hyponymy taken from Eino’s lesson, it will be ISA (symbol of a conducting wire, circuit symbols). That is true because a symbol of a contacting wire is one of the circuit symbols.

Intersemiotic hyponymy was the second-least used sense relation by Ananias (12%) and Eino (12%). It was the third-most used sense relation by Helena (17%). Although it was her third-most used, she used it less than ten times compared to Ananias and Eino who used it more than

twenty times. Intersemiotic hyponymy is divided into two categories. The first category is when the verbal mode is the main class and the visual mode is the sub-class. The second category is when the visual mode is the main class and verbal mode is the class.

Table 15 shows teachers' responses to where and how they can use intersemiotic hyponymy in their Physical Science lessons, apart from the instances observed in their lessons.

Table 15: Teachers' responses to where and how they can use intersemiotic hyponymy in Physical Science lessons.

Question	Similarity (themes)	Differences (themes)
13.4. Give me examples of where and how you can use hyponymy – general to specific, or specific to general	None	• Extraction of iron (T1). • Electrons structure (T1). • Elements in the periodic table (T2).

As indicated in Table 15, only Ananias and Eino could give examples of how they can use intersemiotic hyponymy in Physical Science lessons. Helena responded with a “no” when she was asked whether she could think of a possible of using intersemiotic hyponymy in terms of verbal-visual intersemiotic complementarity in a Physical Science lesson.

Ananias' response revealed that he can use intersemiotic hyponymy when teaching extraction of iron, and atomic structure. When teaching the extraction of iron using a blast furnace, he said: “*You can just have an example of a blast furnace on a poster*”, and verbally indicated that: “*You use this part [for extracting iron], showing them on the poster now*”. In that example, the visual is general because a blast furnace is used to extract different metals, and the visual mode is specific because iron is one of the metals that can be extracted using a blast furnace. Ananias gave another example pertaining to atomic structure stating that: “*We can also use it in electronic structures*. He added that “*Let's say you are having the electronic structure of sodium, you can verbally relate it to other atoms*”. In this example, the visual mode

is specific because it shows a structure of a specific atom, and the verbal mode is general because it is referring to generic structures of atoms.

Eino indicated that he can use intersemiotic hyponymy when teaching about elements in the periodic table, specifically alkaline metals. He said: *“Alkaline metals are elements in group one. When you just say alkaline metals, you generalise everything in group one, but if you look in the periodic table, there are specific elements in that group”*. In this example, the verbal mode is more general because it refers to the whole group one, and the visual mode is specific because it shows specific elements in group one.

Helena’s inability to demonstrate how she can use intersemiotic hyponymy in Physical Science is worth considering. The results from lesson observations showed that hyponymy was her third highest used sense relation of the five. That suggests that teachers use intersemiotic complementarity without necessarily knowing that they are using it (it may be implicit to their practice).

Earlier in this section it was revealed that both the visual mode and the verbal mode have the ability to communicate the main class or a sub-class. Figure 6 shows the of numbers of visual as the main class and verbal as the sub-class, as well as verbal as the main class and visual as the sub-class instances used by the teachers in their Physical Science lessons.

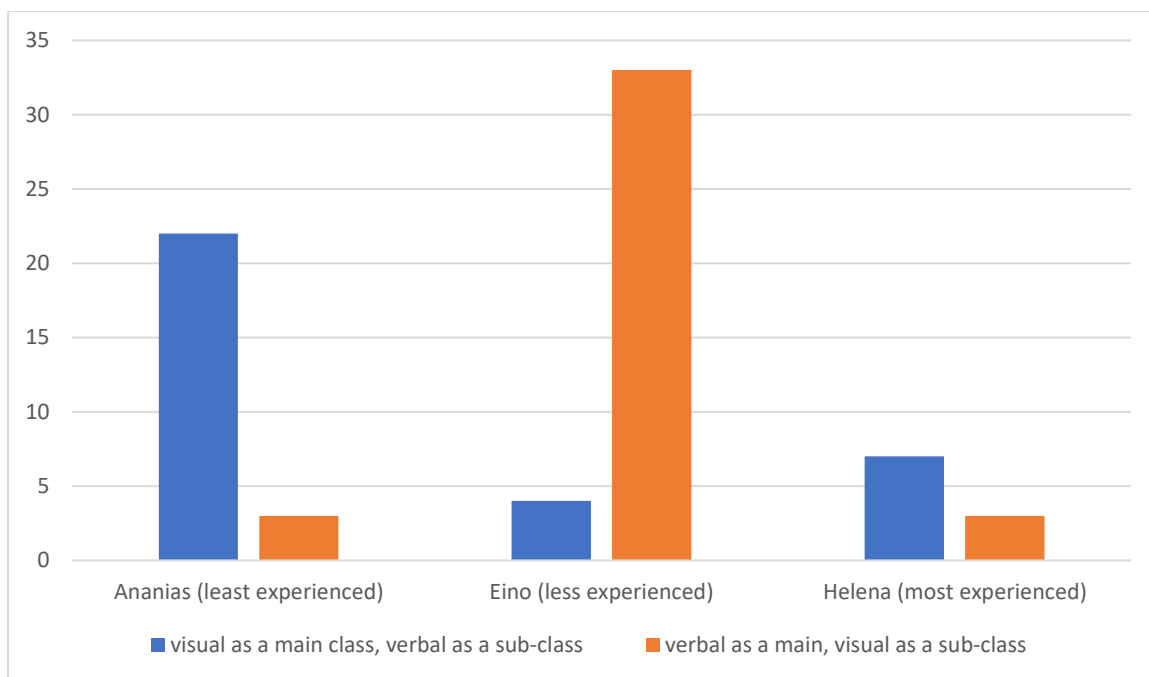


Figure 6: Description of visual as the main class and verbal as the sub-class, and vice versa

The results in figure 6 shows that the least and intermediate experienced teachers used more visual mode as a main class and verbal mode as a sub-class, and used less verbal mode as a main class and visual mode as a sub-class, compared to the intermediate experienced teacher. That trend is not appearing between the intermediate experienced teacher and the most experienced teacher as can be seen in figure 6. That indicates that there are no correspondences between how science teachers use intersemiotic hyponymy in terms of which mode is a main class, which mode is the sub-class and the number of years of science teaching experience.

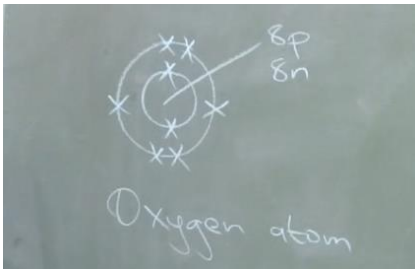
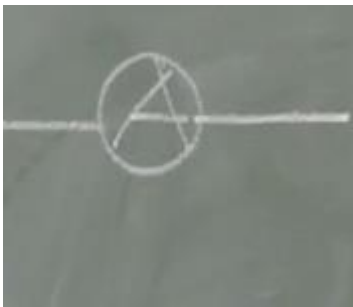
5.3.2.5. *Intersemiotic meronymy*

The use of meronymy in Ananias' lessons included a situation in his second lesson, where he used a visual showing the *atomic structure of an element* and a verbal mode referring to a *nucleus* (see Table 16). In that example, the visual mode shows the whole, and the verbal mode refers to a part of the whole. Intersemiotic meronymy identified in Eino's second lesson included a situation where he used a visual showing a *symbol of an ammeter*, and a verbal mode referring to a *circuit* (see Table 16). In this example, the ammeter is a part of the whole, and

the circuit is the whole. In Helena’s fourth lesson, she used a visual showing the *process of preparation of ombike (oshiwambo traditional)*, and a verbal statement referring to *condensation*. The process of preparation of *ombike* is the whole, and condensation aspect is a part of the whole.

Table 16 shows examples of each category of intersemiotic meronymy observed in the lessons of the three teachers. Only one example is given for each category in the Table.

Table 16: Examples of Intersemiotic meronymy observed in the teachers’ lessons

Sense Relations	Category	Example from lesson observations	Teacher
Intersemiotic Meronymy	Whole: visual, part of the whole: verbal	Verbal: “Nucleus”. Visual: Atomic structure of an element. 	T1
	Whole: verbal, part of the whole: visual	Verbal: “Circuit”. Visual: Ammeter. 	T2

Intersemiotic meronymy was the highest-used sense relation by Ananias (31%) and Eino (34%). Surprisingly, it was the second-least used sense relation by Helena (16%). Like

intersemiotic hyponymy, intersemiotic meronymy has two categories. The first category is when the verbal mode is the whole and the visual mode is part of the whole. The second category is when the visual mode is the whole and the verbal mode is part of the whole.

Table 17 shows teachers' responses to where and how they can use intersemiotic meronymy in their Physical Science lessons, apart from the instances observed in their lessons.

Table 17: Teachers' responses to where and how they can use intersemiotic meronymy in Physical Science lessons

Question	Similarity (themes)	Differences (themes)
13.5. Give me examples of how you can use meronymy – part-whole	None	• Structure of an atom (T1). • Molecules (T1). • lunar eclipse (T2). • Respiratory system (T3).

The responses revealed that all three teachers were able to give examples of how they can use intersemiotic meronymy in terms of verbal-visual intersemiotic complementarity in Physical Science lessons. Ananias indicated that he can use intersemiotic meronymy when teaching the structure of an atom, and when teaching molecules. When teaching the structure of an atom, he said: *"I can explain that an atom is made of three particles, the protons, the electrons and the neutrons, and you can show a picture of an atom where these particles are found"*. In that example, the whole is the atom (visual mode), and the constituent parts are protons, electrons and neutrons (verbal mode). When it comes to molecules, Ananias said: *"We can have a visual of a water molecule, and we explain verbally that it is made up of oxygen and hydrogen atoms"*. In this case, water molecule (visual mode) is the whole, and oxygen and hydrogen (verbal mode) are constituent parts.

Eino indicated that he can use the lunar eclipse when it comes to the inclusion of intersemiotic meronymy. He said:

“From the diagram prospective, we are able to see, how the moon, the earth and the sun are arranged, and how lights are travelling from the sun to the moon. We can be able to see the parts of it in a diagram, while verbally we can just refer it to ‘lunar eclipse’”.

In this example, the lunar eclipse (verbal mode) is the whole, and the moon, the earth and the sun (visual mode) are constituent parts.

Helena was unable to give an example of intersemiotic meronymy that she would use in a lesson for Physical Science. Instead she gives an example from Life Science. She indicated that in Life Science, intersemiotic complementarity can be used when a teacher is teaching respiratory system. She said a teacher can use *“a picture of a respiratory system that is composed of the heart, the blood vessels, blood components, which you can explain verbally”*. In that example, the ‘whole’ is the respiratory system (visual), and constituent parts are the heart, the blood vessels and the blood components, which are explained verbally.

Earlier in this section it was revealed that both the visual mode and the verbal mode have the ability to communicate the whole or a part of the whole. Figure 7 shows the numbers of visual as the whole and verbal as the part of the whole, as well as verbal as the whole and visual as the part of the whole used by the teachers in their Physical Science lessons.

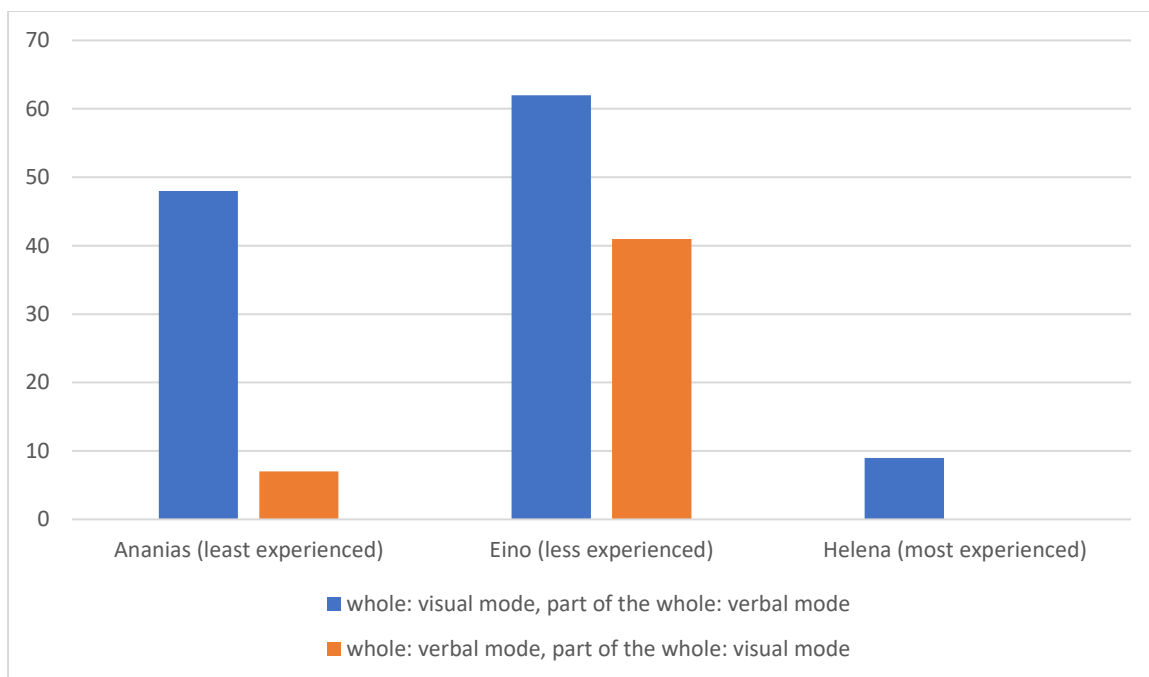


Figure 7: Description of visual as the whole and verbal as the part of the whole and vice versa

Figure 7 shows that all the teachers used visual as the whole and verbal as the part of the whole more often compared to their usage of verbal as the whole and visual as the part of the whole. There is a high usage of verbal as the whole and visual as the part of the whole by the intermediate experienced teacher, compared to the least experienced teacher. That trend is not similar between the intermediate experienced teacher and the most experienced teacher. As can be seen in Figure 7, the most experienced teacher did not even use verbal as the whole and visual as the part of the whole. The results indicate that there are no correspondences between how science teachers use intersemiotic meronymy in terms of verbal as the whole and visual as the part of the whole, and the number of years of science teaching experience.

The lesson observations presented and discussed in this Section (Section 5.3) shows that there are a number of lexical items in the teachers' use of the verbal mode which are semantically related to the meanings expressed in the visual mode. The results and discussions further revealed that the intersemiotic sense relations used by the teachers in their lessons demonstrated that the SFL model is powerful and flexible for the study of semiotic modes (O'Toole, 1995). It was also demonstrated that teachers' communication (which contains both the verbal and visual modes) helps them to communicate scientific concepts in the science classroom.

On average, the intersemiotic sense relations utilised by the teachers' shows that there is a high frequency of intersemiotic meronymy, which is concerned with part-whole relations (Royce, 1999). This may be due to the fact that science is a highly structured subject which consists of scientific facts, concepts, patterns and principles. These requires intersemiotic meronymy to work interactively to support science discourse. There is also a relatively high occurrence of intersemiotic synonymy and repetition. This shows that both the verbal and visual aspects in the science classroom complement each other in maintaining and supporting the central topics.

5.3.3. Overview of the teachers' lessons

I conducted lesson observations over four months for the lessons taught by Ananias, the least experienced teacher, Eino, the intermediate experienced teacher and Helena, the most experienced teacher. As I stated earlier, I observed twelve lessons in total, four lessons per teacher.

I divided each lesson into segments for analysis purpose. As indicated in Chapter Four, the lessons were divided according to the visual used. There were few instances where two visuals used at the same time were combined to form a single segment. There were also instances where a single visual mode was divided into two segments. That happened when the teacher used one visual to explain different concepts or ideas.

5.3.3.1. Overview of Ananias' lessons

As I mentioned previously, I observed four lessons taught by Ananias. In the first lesson, Ananias used five visuals on different occasions. All the five visuals were drawings on the chalkboard. I divided his first lesson into three segments: (The first segment had two pictures which were all used to explain the electric circuits. The second segment had two pictures which were used to explain the connection of resistors in series and parallel circuits. The third segment had a single picture). In those three segments, I identified a total of twenty-nine instances of

verbal-visual intersemiotic complementarity. I also identified two potential uses of the visual mode. Ananias used all five sense relations in this lesson. The most used sense relation was the intersemiotic repetition, which was used nine times, and the least used sense relation was intersemiotic antonymy, which was used three times (see Table 18).

Table 18: Overview of Ananias' lessons

	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Total	%
Total of segments	3	4	6	2	15	
Repetition	9	11	31	6	57	29
Synonymy	5	11	23	3	42	21
Antonymy	3	6	4	1	14	7
Hyponymy	6	5	9	4	24	12
Meronymy	6	11	40	4	61	31
Total sense relations	29	44	107	18	198	100
Potential uses of verbal/visual	2	1	2	1	6	

Ananias used four visuals in the second lesson, three were drawings on the chalkboard, and one was on a poster. As it can be seen in Table 18, I divided the second lesson of Ananias into four segments. In those four segments, I identified a total of forty-four instance of verbal-visual intersemiotic complementarity. I also identified one potential uses of the verbal mode that was not used. The most used sense relation in lesson two was meronymy, which was used eleven times, and the least used sense relation was hyponymy, which was used five times.

In the third lesson, Ananias used seven visuals. Six visuals were drawings on the chalkboard, and one was a poster. As shown in Table 18, I divided Ananias' third lesson into six segments. In those segments, I identified one-hundred and seven instances of verbal-visual intersemiotic complementarity, and two potential uses of verbal modes. The most used sense relation in that

lesson was meronymy, which was used forty times, and the least used sense relation was antonymy, which was used four times.

In his fourth lesson, Ananias used two visuals. Both the visuals were drawings on the chalkboard. I divided the fourth lessons into two segments. I identified eighteen instances of verbal-visual intersemiotic complementarity from the fourth lessons. There was one potential uses of the visual mode but it was not used. The most used sense relation in lesson four was repetition, which was used six times, and the least sense relation used was antonymy, which was used only once (see Table 18).

As indicated in Table 18, a total of one-hundred and ninety-eight instances of verbal-visual intersemiotic complementarity were identified from all the four lessons taught by Ananias. The most-used sense relation was meronymy (used 29%), and the least used sense relation was antonymy (used 7%). Figure 8 shows the proportion of each sense relation used in all the four lessons.

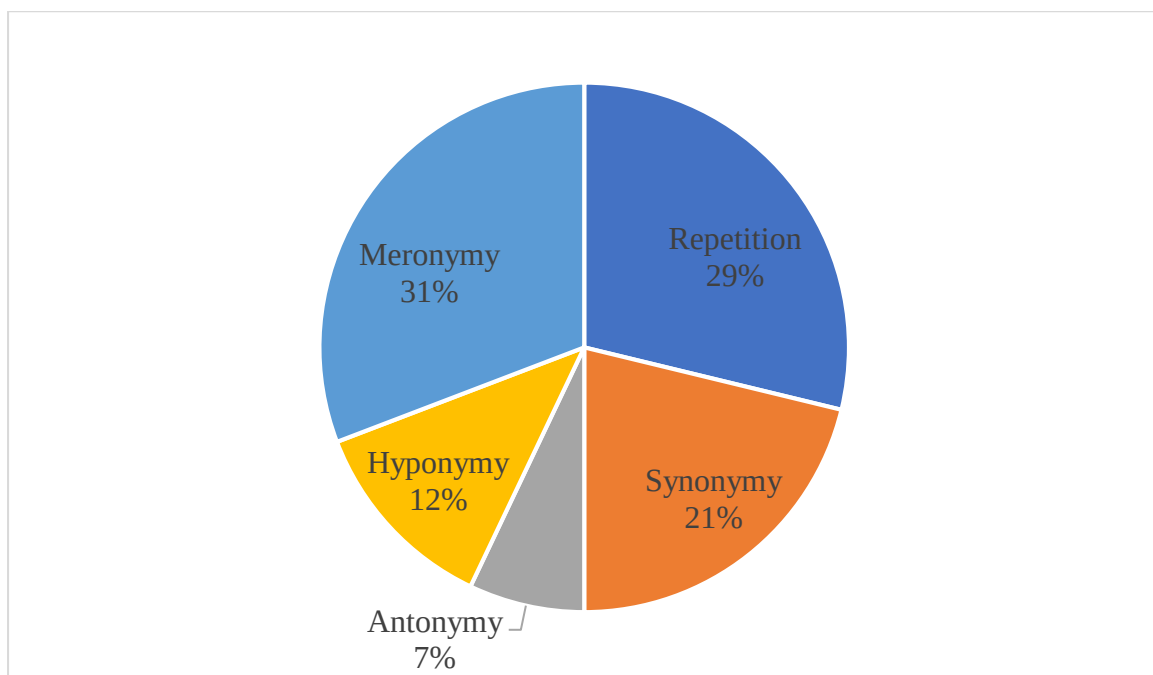


Figure 8: The number of sense relations used in Ananias' four lessons.

5.3.3.2. Overview of Eino's lessons

I observed four lessons taught by Eino. Table 19 shows overview of the number of segments, sense relations and potential uses of the verbal mode or the visual mode in Eino's lessons.

Table 19: Overview of Eino's lessons

	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Total	%
Total of segments	4	8	7	6	25	
Repetition	12	22	36	23	93	30
Synonymy	6	21	24	17	68	22
Antonymy	0	0	6	1	7	2
Hyponymy	1	14	9	12	36	12
Meronymy	19	18	36	31	104	34
Total sense relations	38	75	111	84	308	100
Potential of using verbal/visual	0	0	1	0	1	

In the first lesson, Eino used four visuals. All the four visuals were drawings on the chalkboard. As shown in Table 19, I divided the first lesson into four segments. I identified thirty-eight instances of verbal-visual intersemiotic complementarity from Eino's first lesson. I did not identify any potential uses of the verbal mode or the visual mode that was not used. The most used sense relation in the first lesson was meronymy, which was used nineteen times, and the least used sense relation was hyponymy, which was used only once. Eino did not use antonymy in his first lesson.

Eino used sixteen visuals in his second lesson. All the sixteen visuals were drawings on the chalkboard. I divided the second lesson into eight segments. I identified seventy-five instances of verbal-visual intersemiotic complementarity from Eino's second lesson. Like in his first lesson, I did not identify any potential uses of the verbal mode or the visual mode that was not

used. The most used sense relation by Eino in his second lesson was repetition, which was used twenty-two times. The least used sense relation was hyponymy, which was used fourteen times. As in his first lesson, Eino did not use antonymy in the second lesson (see Table 19).

Eino's third had nine visuals. All the nine visuals were drawings on the chalkboard. I divided the third lesson into seven segments. From the third lesson, I identified one-hundred and eleven instances of verbal-visual intersemiotic complementarity, and one potential uses of the visual mode that was not used. The most used sense relations in that lesson were repetition and meronymy, which were used thirty-six times each. The least used sense relation was antonymy, which was used six times (see Table 19).

Eino used eight visuals in his fourth lesson. All the eight visuals were drawings on the chalkboard. I divided his fourth lesson into six segments. I identified eighty-four instances verbal-visual intersemiotic complementarity. I did not identify any potential uses of the verbal mode or the visual mode which was not used. The most used sense relation was meronymy, which was used thirty-one times, and the least used was antonymy, which was used only once (seen Table 19).

As indicated in Table 19, a total of three-hundred and eight instances of verbal-visual intersemiotic complementarity were identified from all Eino's four lessons. The most used sense relation in all the four lessons was meronymy (used 34%), and the least used sense relation in all the four lessons was antonymy (used 2%). Figure 9 shows the total number of each sense relations used by Eino in all four lessons.

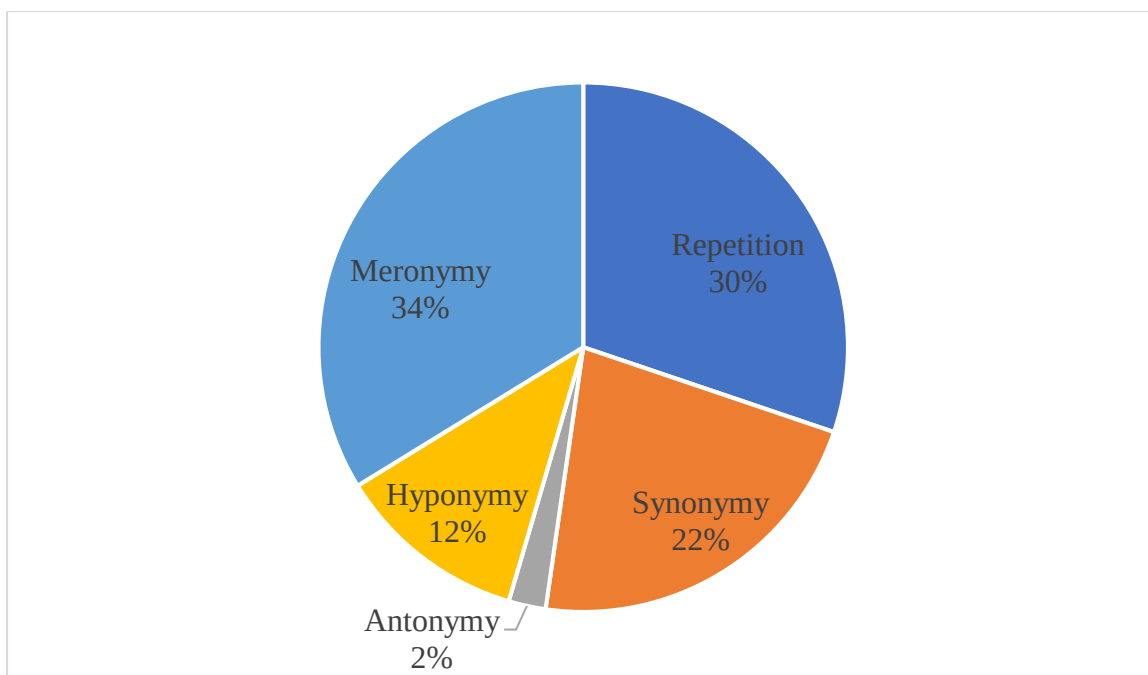


Figure 9: Number of sense relations used in Eino's four lessons.

5.3.3.3. Overview of Helena's lessons

Like the other two teachers, Ananias and Eino, I observed four lessons taught by Helena. Table 20 shows the overview of the number of segments, sense relations and potential uses of the verbal mode or the visual mode in Helena's lessons.

Table 20: Overview of Helena's lessons

	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Total	%
Total of segments	2	2	1	1	6	
Repetition	4	7	4	4	19	33
Synonymy	5	2	3	3	13	22
Antonymy	1	2	3	1	7	12
Hyponymy	4	3	2	1	10	17
Meronymy	5	0	0	4	9	16
Total sense relations	19	14	12	13	58	100
Potential uses of verbal/visual	1	2	0	4	7	

Helena used two visuals on her first lesson that I analysed. One of the visuals was a drawing on the chalkboard, the other was a copy from a textbook. I divided the first lesson into two segments. I identified nineteen instances of verbal-visual intersemiotic complementarity from Helena's first lesson. There was one potential uses of the visual mode that was not used. The most used sense relations in the first lesson were synonymy and meronymy, which were used five times each. The least sense relation used was antonymy, which was used only once (see Table 20).

In the second lesson, Helena used three visuals. The visuals were a drawing on the chalkboard, a picture in a handout, and a copy of a picture from a textbook. I divided the second lesson into two segments. A total of fourteen instances of intersemiotic complementarity were identified from the second lesson. There were two potential uses of the visual mode. The most used sense relation in the second lesson was repetition, which was used seven times, and the least used sense relations were synonymy and antonymy, which were used twice each. Meronymy was not used in the second lesson (see Table 20).

Only one visual was used in Helena's third lesson. That visual used was a copy of a picture from a textbook. I only had one segment in the third lesson. Twelve instances of verbal-visual intersemiotic complementarity were identified from that segment. There were three potential uses of the visual mode. The most used sense relation was repetition which was used four times. The least used sense relation was hyponymy, which was used twice. As in the second lesson, meronymy was not used in third lesson (see Table 20).

In the fourth lesson, Helena used only one visual. That visual was a drawing on the chalkboard, which formed only one segment. In that segment, thirteen instances of verbal-visual intersemiotic complementarity were identified. There were four potential uses of the visual mode. The most used sense relations were repetition and meronymy, which were used four times each. Both antonymy and hyponymy were used once each, making them the least used sense relations, as it can be seen in Table 20.

As indicated in Table 20, a total of fifty-eight instances verbal-visual intersemiotic complementarity were identified from all Helena's four lessons. The most used sense relation in all the four lessons was repetition (used 33%), and the least used sense relation in all the four lessons was hyponymy (used 12%). Figure 10 shows the total number of each sense relation used in all of Helena's lessons.

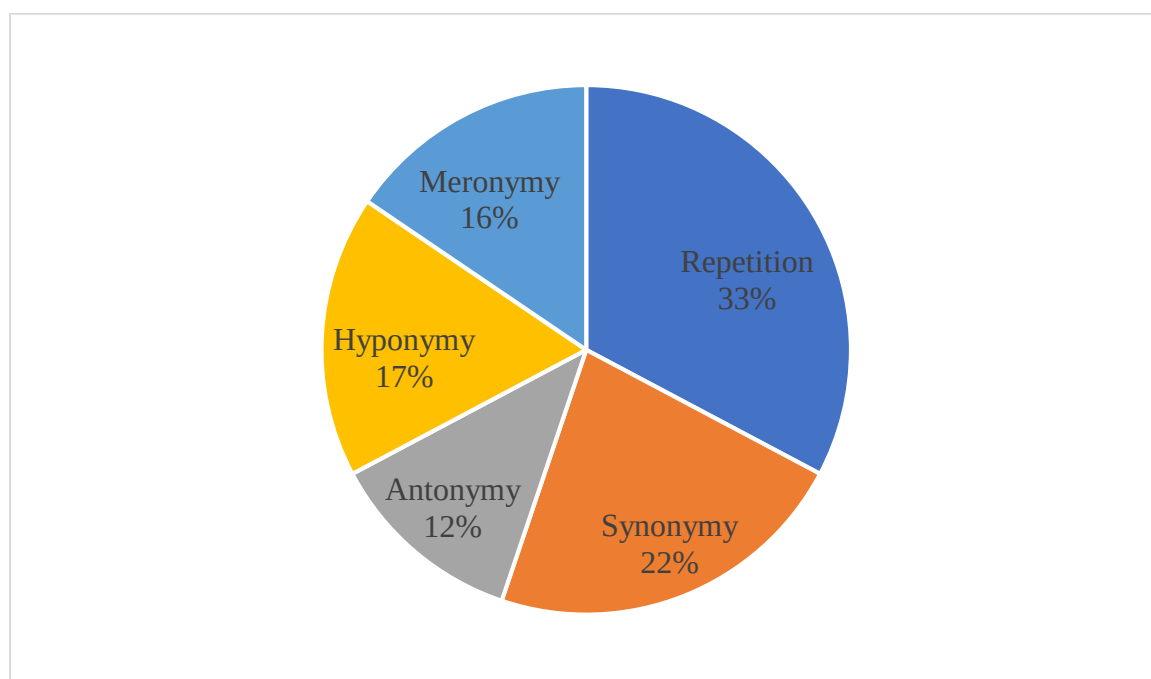


Figure 10: The number of sense relations used in Helena's four lessons

5.3.4. The use of intersemiotic complementarity and the number of years of Physical Science teaching experience

As mentioned in Chapter Four and in previous sections, the three teachers involved in this study have different years of Physical Science teaching experience. I selected teachers with differing years of Physical Science teaching experience in order to explore the correspondences (if any) between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience (research question 2). In this section, I compared how teachers with different Physical Science teaching experiences used verbal-visual intersemiotic complementarity.

Figure 11 shows how many times each intersemiotic sense relation is used by the teachers. In the graphs, the teachers are arranged in the ascending order of their science teaching experiences. Figure 12 shows the total number of sense relation used by each teacher.

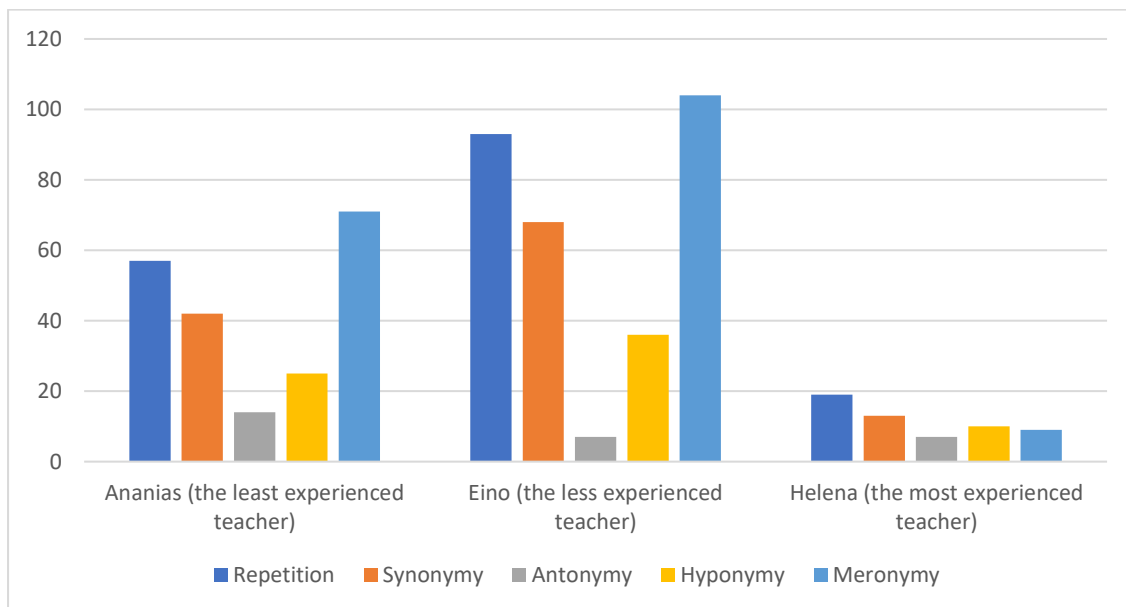


Figure 11: The number of each intersemiotic sense relation used by the teachers

Figure 12 shows the total number of sense relation used by each teacher.

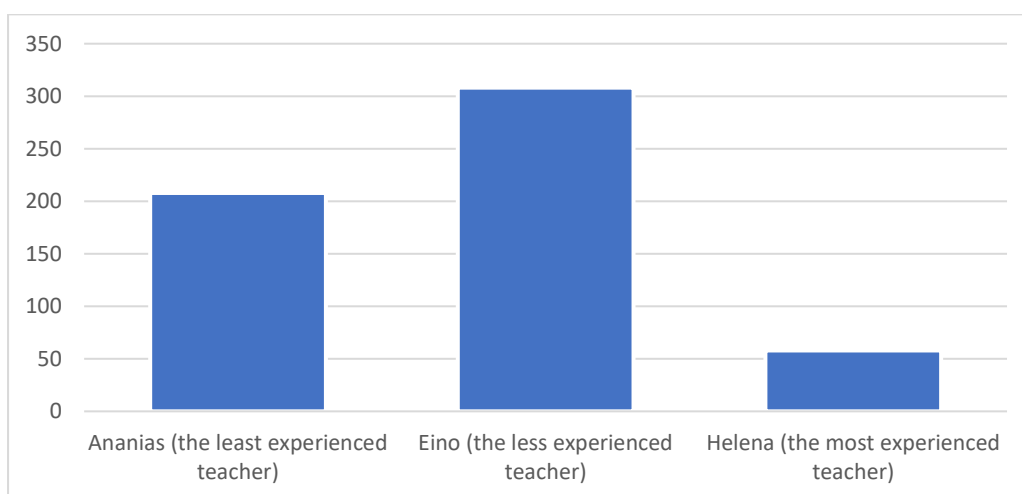


Figure 12: Total number of sense relations used by each teacher

The least experienced teacher, Ananias, who taught Physical Science for less than half-a-year used intersemiotic complementarity more often than the most experienced teacher, Helena, who taught Physical Science for eleven years. As can be seen in figure 12, Ananias used intersemiotic complementarity of the verbal and visual modes 208 times, compared to 58 times for Helena. In terms of specific intersemiotic sense relations, again, the least experienced teacher used each intersemiotic sense relation more than the most experienced teacher. On the other hand, Figure 12 shows that Eino, who taught Physical Science for 7 years (more experienced teacher than Ananias, but less experienced than Helena), used intersemiotic complementarity 308 times. He used intersemiotic complementarity more than both the least experienced teacher and most experienced teacher. In addition, Figure 12 shows that Eino used four of the five intersemiotic sense relations more than Helena. They used intersemiotic antonymy equally. In comparison with Ananias, Eino used almost all intersemiotic sense relations more than Ananias, except intersemiotic antonymy, which Ananias used more than both Eino and Helena.

Though it is widely accepted that teachers' experience influences their cognition and representation (Hogan, Rabinowitz & Craven, 2003), the results of this study are in contradiction with the above notion. A teacher who has less than six months of science teaching experience used verbal-visual intersemiotic complementarity more often than the teacher who has more than ten years of science teaching experience. The results also revealed that the least experienced teacher used less verbal-visual intersemiotic complementarity compared to the intermediate experienced teacher.

The most experienced teacher did not only use verbal-visual intersemiotic complementarity the lowest, on average, she also used fewer visuals in her lessons. The possible reasons why some experienced teachers use fewer visual compared to inexperienced teachers includes the opinion that "less experienced teachers use visual aids when topics and subject matters are difficult to explain" (Baser, 2013, p. 16), and experienced teachers use fewer visual aids for such purposes. Another possible reason why the least experienced and the intermediate experienced teachers used more visuals than the experienced teacher may be due to the fact that teachers were observed teaching different topics. There is a possibility that some topics have more potential for the use of visuals than others.

5.4. The types of representations on which intersemiotic complementarity tends to focus (phase 2)

As discussed in the previous sections, intersemiotic sense relations were found to occur regularly in the teachers' lessons. Each of the intersemiotic complementarity instances identified in this study (through sense relations) was found to focus to one of the following four intersemiotic complementarity types:

1. Physical material
2. Processes
3. Symbolism
4. Resemblance

Although the four types of intersemiotic complementarity emerged from the data, some have been identified and used before in other semiotic studies. The types of intersemiotic complementarity previously reported in the literature, are symbolism and resemblance. While symbolism is used in this study in the same context in which it is used by other semiotic scholars, resemblance is used slightly differently. Physical materials and processes appear not to have been previously reported on in other semiotic studies. In this section, I present and discuss how physical materials, processes, symbolism and resemblance are used across the intersemiotic sense relations.

1. Physical materials

This type of intersemiotic complementarity involved teachers using the visual mode (both real photos and sketches) that represents physical objects. The use of sense relations for physical materials varies across teachers and type of intersemiotic sense relations. Table 21 shows how the teachers employed intersemiotic sense relations in their lessons focusing on physical materials.

Table 21: Physical materials used in the verbal-visual intersemiotic complementarity

Sense relations	Visual mode	Verbal mode
Repetition	Windmill 	“Windmill”
Synonymy	Conductor wire connected from the roof to the ground. 	“Earthing system”.
Antonymy	Condenser. 	“Evaporation”.

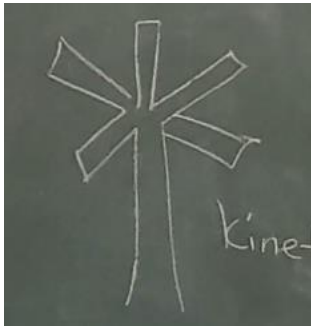
Hyponymy	House. 	“Modern house”.
Meronymy	Windmill. 	“blade”.

Table 21 shows that most of the physical material representations that interact semantically with the verbal aspect of the teachers to realise intersemiotic complementarity were sketch drawings on the chalkboard. Although the visual mode used are sketches, as indicated in the literatures describing similar studies, those visual mode are used to represent reality.

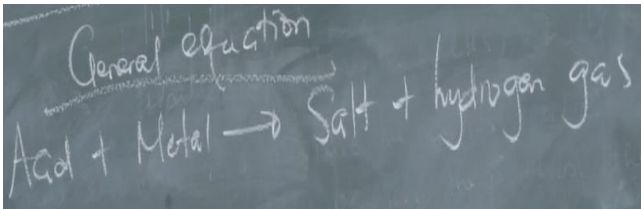
The use of visual mode representing real objects help learners to make connections to things that they already know and see in reality (Quillin & Thomas, 2015). For example, learners who grew up in the village were exposed to the condenser used in the preparation of Oshiwambo traditional gin. A visual can help them to make connections to what they grow up seeing. The visual mode representing physical materials also promotes better learners’ comprehension of scientific concepts and principles (Johnson & Reynolds, 2005). They promote active learning, leading to improvement in learners’ construction of scientific knowledge (Johnson & Reynolds, 2005).

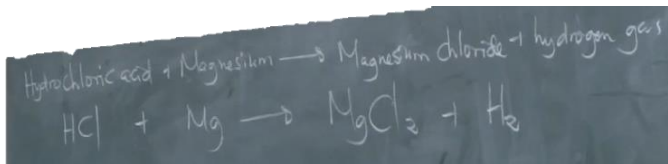
The use of visual mode by the participating teachers to represent physical materials in their lessons is in line with some of teachers' understanding about the uses of visual mode in the science classroom. For example, when asked to state the importance of the visual mode in science classroom, Eino responded that it brings reality to the classroom.

2. Processes

Processes involved the use of intersemiotic sense relations to represent scientific processes and chemical reactions. Scientific processes in this study refer to the practices employed in science, or in everyday life to uncover knowledge or to demonstrate a concept through experiments. On the other hand, chemical reactions include the chemical equations, both words and formulas, and changes of a substance into a new substance that has a different chemical identity (Ghulam & Nyberg, 2014). Table 22 shows how the teachers employed intersemiotic sense relations in their lessons focusing on processes.

Table 22: Intersemiotic sense relations employed by the teachers focusing on processes

Sense relations	Visual mode	Verbal mode
Repetition	General equation of the reaction between acid and metal. 	“General equation of the reaction between metals and acids”.
Synonymy	Flame. 	“Heat”.

Antonymy	None	None
Hyponymy	Word equation for the reaction between hydrochloric acid and magnesium.  Hydrochloric acid + Magnesium → Magnesium chloride + hydrogen gas $\text{HCl} + \text{Mg} \rightarrow \text{MgCl}_2 + \text{H}_2$	“equations between acids and metals”.
Meronymy	The preparation of Oshiwambo traditional gin (Ombike). 	“condensation”.

As shown in Table 22, the teachers employed four of the five intersemiotic sense relations in their representation of processes in the science classroom. The use of intersemiotic complementarity to represent processes makes it possible for science teachers to explain complex phenomena to learners (Richards, 2003). For example, the preparation of Oshiwambo traditional gin may not be done in the classroom because of the complexity involved in its preparation and the fact that it is an alcoholic beverage and school students are below the legal age for drinking alcohol. As argued by Shabiralyani and colleagues, verbal-visual intersemiotic complementarity used by the teachers focusing on processes helped save time during the preparing and presenting of the lessons (Shabiralyani et al., 2015). In the example of making Oshiwambo traditional gin, the teacher was able to present the whole process within ten minutes, with the help of intersemiotic sense relations. This is significant when time is a premium in school science curricula.

Apart from being involved in the teachers' lessons, processes were also identified by some of the participating teachers as one of the instances in science where they use intersemiotic

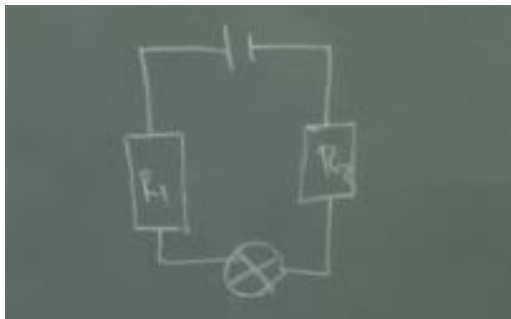
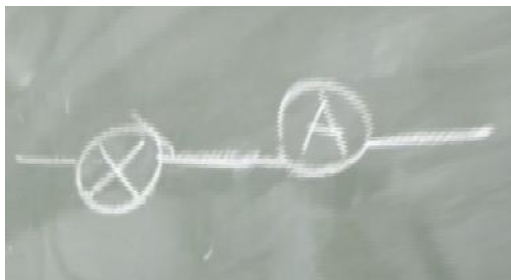
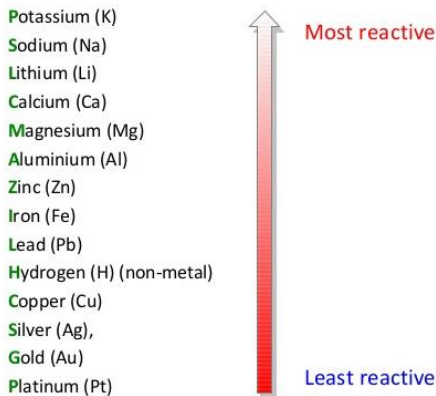
complementarity. For example, Ananias indicated “*Some of the processes you cannot really explain them without a picture to show*”. This is supported by Morrison (2012) who indicates that fundamental science process skills can be easily demonstrated using visual mode.

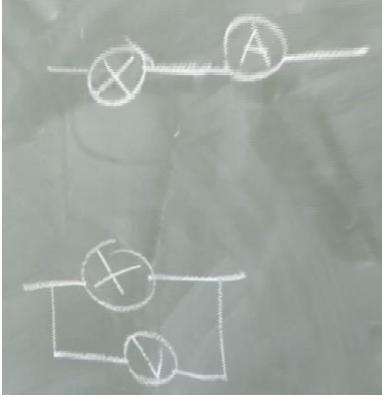
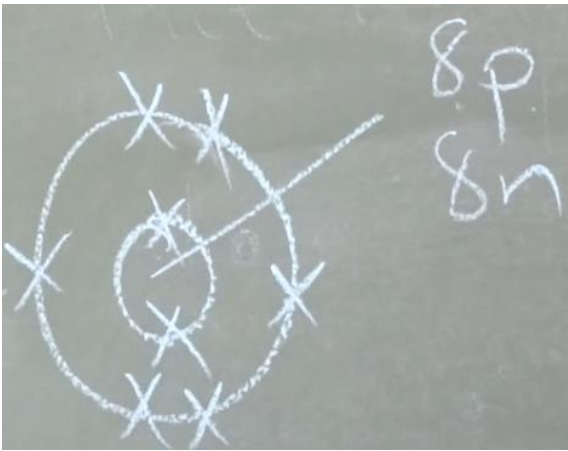
As evident from Table 22, the science teachers seldom involved intersemiotic antonymy in the verbal-visual intersemiotic complementarity when representing processes. Although the teachers did not use intersemiotic antonymy to represent processes, Ananias indicated that he could use it. He said: “*You can have a diagram whereby you are having an arrow pointing from solid to liquid, but in your explanation, you can include moving back from liquid to solid*”. This is an indication that although the teachers did not involve intersemiotic antonymy when representing processes in the verbal-visual intersemiotic complementarity, there is a possibility for its inclusion.

3. Resemblance

Resemblance appeared in Bradley’s (2016) categories of iconic representations. Bradley (2016) used resemblance to refer to the information which has a direct likeness to the objects it represents – for example, a camera icon for a smartphone camera app. In this study, this type of intersemiotic complementarity involved the teachers using a visual which has a direct likeness to the objects, or a visual that depicts a common scientific example. Examples of how the participating teachers used intersemiotic sense relations focusing on resemblance is shown in Table 23.

Table 23: Intersemiotic sense relations employed by the teachers focusing on resemblance

Sense relations	Visual mode	Verbal mode
Repetition	Two resistors in a series connection. 	“Series connection”.
Synonymy	An ammeter connected in a series connection. 	“An ammeter is connected in line with a component”.
Antonymy	Decrease of the intensity of the red colour. 	“The reactivity series increases as the arrow goes up”.

Hyponymy	Two types of connections. 	“Connection across the component”.
Meronymy	An atomic structure of an element. 	“Electrons”.

As shown in Table 23, the teachers involved all the intersemiotic sense relations towards resemblance. Resemblance used by the teachers includes both printed and chalkboard drawings. Resemblance can help learners to visualise and relate what they see in the classroom (visually) to what is actually being represented. As Cook (1992) argued, in the moment learners see resemblance, they grasp the meaning. This is important because it helps teachers to introduce learners to important scientific activities and skills. For example, resemblance is used to introduce learners to the two types of connections. A teacher can successfully help learners to understand the series and parallel connections, without showing learners the actual connections as would be necessary in schools with limited or no resources. The use of resemblance to represent parallel and series circuit also helps the teacher to present details of differences between scientific concepts. Resemblance is crucial in this case because learners might not be able to differentiate the types of connections in a real building or street lights. If they learn the types of connections in the classrooms, they are likely to relate their understanding to real life afterwards.

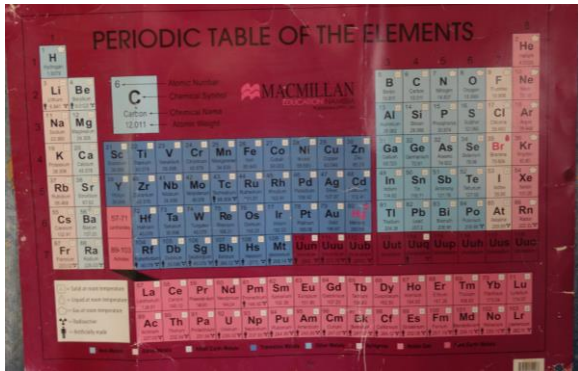
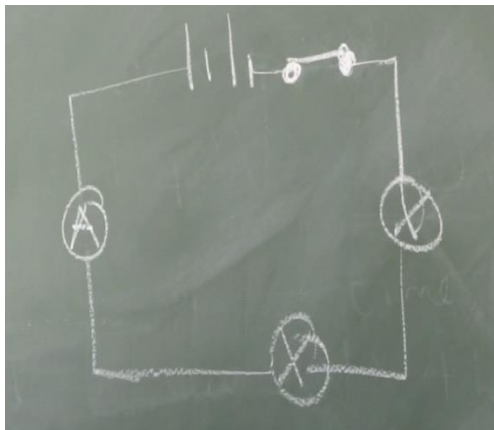
Resemblance also helped the teachers to represent phenomenon which are not directly visible to the human eye due to their scale, and complex phenomenon such as industrial processes in chemical plants. This is supported by Cook (2006), who notes that the visual mode is important in making visible phenomenon that are too small and too larger to be seen. In Table 23, an atomic structure is one example of small-scale concept. It is impossible for learners to see a real atom of an element. This means without the use of a resemblance, learners may find it difficult to understand what an atom looks like and what its component parts are.

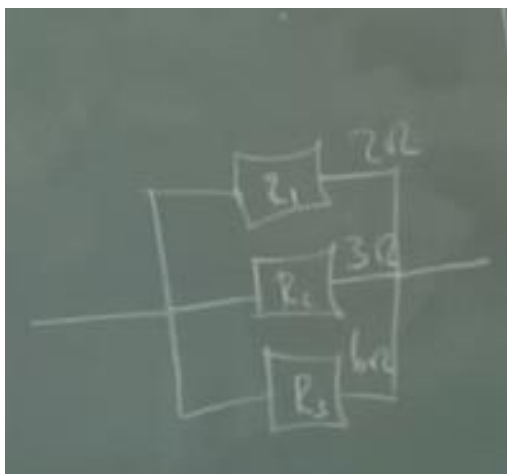
4. Symbolism

Symbolism appeared in the early writings of Peirce as one of the forms for representation of information. Peirce defined a symbol as “a sign which refers to the object that it denotes by virtue of a law, usually an association of general ideas” (Peirce, 1955, p. 102). Symbolism is used here to refer to the word ‘symbol’ as used in general language derived from the Greek verb *symbolleîn* ‘to throw together’ and its noun *symbolon* ‘mark’, ‘emblem’, ‘token’ or ‘sign’ (Razaq, 2011). Thus, symbolism refers to an object, picture, or letters which represents or stands for something else (Razaq, 2011). Examples of symbols include numbers and alphabet. Symbols also include pictures – for example, a *cross* for Christianity, and *bald eagle* for United State of America (USA). In Physical Science, symbols include *crosses* and *dots* for electrons, and *letters* as chemical symbols in the periodic table of elements. Science teachers use a large range of symbols.

Symbolism involved the teachers using letters, numbers and symbols to represent information. It also included teachers using images that represent words or concepts. Table 24 shows how the teachers employed intersemiotic sense relations in their lessons focusing on symbolism.

Table 24: Intersemiotic sense relations employed by the teachers focusing on symbolism

Sense relations	Visual mode	Verbal mode
Repetition	Symbol of a bulb 	“bulb”.
Synonymy	Letters in the periodic table. 	“chemical symbols of elements”.
Antonymy	Closed switch. 	“Open switch”.

Hyponymy	Symbol of a cell 	“Circuit symbols”.
Meronymy	Resistance of specific resistors. 	“Total resistance”

As shown in Table 24, the teachers used symbolism to represent all the intersemiotic sense relations. It appears that teachers commonly use symbols which are not words. This is in support of Port (2000) who claim that the most common symbols are not words. As noted by Bradley (2016), there is no similarity between the signifier and the signified in most of the symbols used by the teachers – for example, a *circle with a cross inside* does not have a likeness to a *bulb*, and a *short line alongside a long line* does not have likeness to a *cell*. Bradley (2016) argues that the connection between the signifier and the signified is normally culturally learned. For learners to understand that a *circle with a cross inside* represents a bulb, this need to be explained to them.

As indicated in literature, the teachers used symbols to label scientific drawings to support writing and recording. This can be seen in the last example (meronymy) shown in Table 24.

Symbols were used in the visual to label the resistors and indicate their readings. In the periodic table, symbols were used to represent elements. Apart from labelling, the teachers involved in this study also used symbolism to help learners to visualise the meanings of words – for example ‘closed switch’. This helps teachers to mediate the understand science concepts which are difficult to understand through words alone (Wellington & Wellington, 2002).

5.5. Additional findings

In this section I look at the findings which are relevant to the intersemiotic complementarity of the verbal and visual modes in science classrooms, but not directly relevant to the research questions. First, I present the perception of participating teachers about the importance of the verbal and visual modes, as well as the teachers’ understanding of the uses of visual mode in Physical Science lessons. I then focus on the perceptions of the participating teachers about the inclusion of the verbal mode, visual mode and verbal-visual intersemiotic complementarity in science teachers’ training. Finally, I focus on at the potential uses of the verbal and visual modes (Appendix L).

1. Teachers’ perceptions about the verbal mode and the visual mode in science classrooms

Table 25 shows teachers’ responses about what they think are the importance and uses of the verbal mode and the visual mode in Physical Science classrooms.

Table 25: Teachers' perceptions about the importance and uses of the verbal mode and the visual mode

Question	Similarity (themes)	Differences (themes)
3(1) When you started teaching you think teacher talk is important in science teaching?	• Verbal mode is important (T1, T2, T3). • Verbal helps learners to understand scientific terms (T1, T2).	• The tone of the teacher attracts learner's attention (T2). • Teacher's tone makes the class active (T2).
3(2) What about now, is there a change in your thinking? If yes, give examples.	• There is a change (T1, T2, T3). • Teacher's tone needs to be clear (T2, T3).	• Verbal should focus more on content and not on scientific words (T1). • More experienced teachers are open (T2).
4(1) When you started teaching did you think visuals are important in science teaching.	• Visuals are important (T2, T3).	• Not really important (T1).
4(2) What about now, is there a change in your thinking? If yes, give examples.	• Visuals are important (T1, T2, T3). • Learners learn better by seeing (T1, T2).	• Visuals are important for remembering (T1). • Visuals make a lesson more practical (T2). • Use visuals to explain scientific terminology (T3).
5. Which one do you consider more important in a Physical Science classroom, verbal (teacher talk) or visuals?		• Verbal is more important than visual (T1). • Verbal is only important when combined with visuals (T1). • Visual is more important than verbal (T2). • Visuals bring reality to the classroom (T2). • Enhance long memory (T2). • Verbal and visuals are equally important (T3).
6. What do you use visuals for?		• Emphasises important points (T1). • Demonstrate the process (T1). • Source of teaching aids (T2). • Long term memory (T2). • Attract learners' attention (T3).

As mentioned in Chapter Two, the verbal communication between a teacher and learners influences the classroom environment and quality of the instructional program (Webster & Johnson, 1987). The visual mode provides alternative ways of representing information and helping learners to obtain knowledge that they may not get from the verbal mode alone (Mayer et al., 1996). The discussion of this section is structured into the following categories:

- Importance of the verbal mode in Physical Science lessons
- Importance of the visual mode in Physical Science lessons
- What the teachers consider more important between the visual mode and the verbal mode
- Uses of the visual mode in Physical Science lessons

Importance of verbal mode in Physical Science lessons

Table 25 shows that the participating teachers share both similar and different views about the importance of verbal mode in Physical Science lessons. The responses revealed that all three participating teachers acknowledged the importance of the verbal mode in Physical Science lessons when they started teaching. The least experienced teacher, Ananias, and the teacher with intermediate experience, Eino, indicated that the teacher's verbal mode helps learners to understand scientific terms. Ananias said: *"When you are talking, you explain some of the scientific terms, and learners always copy these scientific terms from you when you explain"*. This is supported by Carrier (2011) who argues that teachers' verbal mode helps students to communicate scientifically. Since verbal mode helps learners to learn scientific terms, Eino understands that a teacher's wrong pronunciation of scientific words can lead to misconception of scientific concepts among learners. He said:

“You should also consider how you pronounce your words, so that you don’t confuse those children in the class. As learners they always have that thing of saying whatever the teacher is saying is always correct”.

Eino’s understanding is supported by (Yani, 2012, p. 197) who argues that teachers are the role models of most learners, and “most learners will believe that what their teachers do is the correct thing”.

All the three teachers indicated that as they get more experienced their perceptions about the importance of verbal mode in Physical Science classrooms also changes. The intermediate and most experienced teachers, Eino and Helena, indicated that after teaching for several years, they understand that the tone of the voice of the teacher is important in the classroom. Eino said: *“As a teacher in the class you should make sure that your tone is very clear to the learners”*. He also indicated that the tone of the teacher’s voice can attract learners’ attention and make the class active. Helena understands that: *“The way you explain things, even the voice, the more you are gaining experience the better you are becoming”*. She said even the general presentations of teachers change as they gain more experience. The importance of a teacher’s voice tone is also supported by Voice (1996) who argues that a teacher cannot expect learners to listen in a positive way if the tone of the teacher is harsh and unfriendly.

When he started teaching, Ananias had an understanding that the verbal mode helps learners to understand scientific knowledge. He acknowledges that as he gains more teaching experience, he is understanding more that the verbal mode needs to focus more on understanding content than induction to scientific words. He said:

“I only thought that when you are talking, you concentrate more on the scientific terms. You include them as much as possible in the lesson so that learners can get to know them, but now the most important thing is the content itself. That is what I have noticed. The content is more important than just scientific words.”

He holds the view that science teachers need to consider how they should use scientific language when talking to learners. He is supported by scholars like Wellington and Osborne (2001), who point out that scientific language is not just specialist vocabulary. It is possible to discuss a topic scientifically without using substantial technical vocabulary (Wellington & Osborne, 2001).

Importance of the visual mode in Physical Science lessons

Table 25 shows that there are similarities and differences in the participating teachers' views about the importance of visual mode in Physical Science lessons. The least experienced teacher, Ananias indicated that he *"never thought that visuals are important because those things of teaching and things are not really available, you only use a text book"*. He indicated that after now teaching for several months, he knows that the visual mode is important. Eino and Helena, indicated that they knew that the visual mode is important in Physical Science lessons when they started teaching. They also indicated that as they became more experienced, they tended to understand the importance of visual mode more. Wolff et al. (2016) agrees that as teachers gain more teaching experience, they get more knowledge about classroom problems and events which drive their understanding of the importance and use of the visual mode.

The responses further indicated that Ananias and Eino believe that visual mode is important because learners learn better by seeing. Ananias also understands that as learners see things, it can help them to remember. This is supported by Shabiralyani et al. (2015) who claim that 83% of what is learned by learners is from the sense of sight, and people generally remember 30% of what they see. Shabiralyani et al. (2015, p. 226) further state "proper use of visual aids helps to retain more concepts permanently".

The responses also revealed that Eino understands that the visual mode is important because it makes a lesson practical. Through the visual mode, learners can see what the teacher is talking about, which according to Shabiralyani et al. (2015) can create an environment of interest for the learners.

Helena, the most experienced teacher, indicated that the visual mode is important to explain scientific terminology. She said: *“Now I am getting more experience, I am using more visuals to explain science terminologies compared to the time when I was not experienced”*. The importance of visual mode in learning new terminology is reinforced by Shabiralyani et al. (2015, p. 226) who argue that “visual aids help to increase the vocabulary of the students”. Regardless of Helena’s understanding of the importance of the visual mode, the results from lesson observations showed that she uses fewer visuals compared to the other two teachers, Ananias and Eino.

What the teachers consider more important between the visual mode and the verbal mode

The teachers have mixed views about whether the verbal or visual mode is more important in Physical Science lessons. Ananias holds the view that verbal mode is more important, saying *“Teacher talk is more important, but it will only be important if you integrate it with some visuals as well”*. This is supported by Butcher and Aleven (2007), Van Meter (2001), Mayer (2001), and Van Meter, Aleksic, Schwartz and Garne (2006). For example, Mayer (2001) notes that instructional presentations that contain both the verbal and visual modes are more beneficial than presentations that have verbal mode alone.

Eino suggests that the visual mode is the more important than the verbal mode in Physical Science lessons. He stated:

“The more important one is the visual. Learners learn better by touching and seeing. A visual is something that they can be able to see, unlike when you are just telling them”.

Eino’s views correspond with his use of the visual mode. Among the three teachers that participated in the study, he is the one who used the most visual mode. With regard to his views, it should be noted that there is a general consensus among teachers and researchers that visual

materials are only effective in the classrooms when used as a supplement to verbal communication, and not as a substitute for the verbal mode (Hoban & Ormer, 1970). Helena, who used fewer visual mode in her lessons, compared to the other two teachers, indicated that the verbal mode and the visual mode are equally important in Physical Science classrooms.

Uses of the visual mode in Physical Science lessons

The teachers' responses revealed that they use visual mode for different purposes in Physical Science lessons. Ananias, the least experienced teacher indicated that: *"I normally use them when I want to emphasise a very important point.* The use of visual mode to emphasise important points is also outlined in the University of Leicester's *Visual Aids Guide*, which points out that teachers can use the visual mode to highlight main points and technical information in the lessons (Learning Development, 2009). Araya, Farsani and Hernández (2016) also assert that the visual mode is used to communicate core concepts to learners.

Eino, the intermediate experienced teacher indicated that he uses the visual mode to visualise concepts. He believes that the visual mode brings reality to the classroom:

"There are some things which are too theoretical, something that they never saw it, they will be having a lot of imaginations of how it looks like. But once you bring it into a class as a visual, now learners can be able to create that kind of mindset or that kind of memory that will last longer in their minds".

As argued by Bobek and Tversky (2016), some topics in science are difficult for learners to grasp because they are outside learners' experiences. In that regard, visualisation can be invaluable because visual explanations can show parts and processes of complex systems directly. Using them compliments verbal explanations (Bobek & Tversky, 2016). Eino further said:

“If the child has seen one [a visual of a certain concept] in his/her life time, that child will not be able to forget. That has created a permanence, it can become a permanent memory in that child”.

McCabe (2014) reported that the use of the visual mode enhances the number of routes for retrieval, and that leads to enhancement of memory. In addition, Udomon et al. (2013) maintains that the use of the visual mode leads to better memory retention than the use of the verbal mode.

Helena’s responses indicated that she uses the visual mode *“just to attract learners’ attention”*. Attraction of learners’ attention is included in the roles of visual mode in teaching and learning outlined by Cook (2012), where she indicates that teachers use the visual mode in the classroom to attract learners’ attention and to motivate them.

Teachers’ views about the usefulness of the visual mode in Physical Science lessons is likely to influence their ability to use the visual mode effectively, or some combination of the verbal and visual modes in their classrooms. The teacher who used fewer visuals in her lessons held the perspective that the visual mode is used in science lessons for attracting learners’ attention.

2. Inclusion of verbal-visual intersemiotic complementarity in science teachers’ training

Table 26 shows teachers’ perceptions about the inclusion of the verbal-visual intersemiotic complementarity in science teachers’ training.

Table 26: Teachers’ perceptions about the inclusion verbal-visual intersemiotic complementarity in science teachers’ training

Question	Similarity (themes)	Differences (themes)
7.1. In your teacher training did you encounter the issue of teacher-talk?	• The verbal mode is not really included (T1). • The verbal mode is included very little (T2).	• The verbal mode was included (T3).
7.2. In your teacher training did you encounter the issue of visuals	• Visual is included (T1, T2, T3).	• How to use videos (T1) • Visual training was minimal (T2). • How to use visuals in the classroom comes with experience (T2). • Inclusion of visuals is not sufficient (T2). • How to use diagrams (T3).
7.3. In your teacher training did you encounter the issue of integration of teacher-talk and visuals? (verbal-visual intersemiotic complementarity)?	• Verbal-visual intersemiotic complementarity was not included (T1, T2).	• Too little Verbal-visual intersemiotic complementarity was included (T2). • Teachers learned on their own how to use verbal-visual intersemiotic complementarity (T2). • Verbal-visual intersemiotic complementarity was included (T3).

The study conducted by Shabiralyani et al. (2015) recommended that universities and colleges should suggest to their student teachers that visual aids will be helpful in enhancing the learning process for students. The discussion in this section is structured as follows:

- Inclusion of the verbal mode in science teachers’ training
- Inclusion of the visual mode in science teachers’ training
- Inclusion of verbal-visual intersemiotic complementarity in science teachers’ training

Inclusion of verbal mode in science teachers' training

The participating teachers have different views about how verbal mode was included in their professional training. Ananias left the university less than eight months ago and indicated that the teacher's verbal communication in a science classroom was not part of his science teacher training. However, he acknowledges that teachers' verbal communication was involved in some of their modules. He said:

“Hmm, not really, but it is involved in some of the modules that we did. Just like in the sense on how to understand learners. Just there, not really how to teach, because we did teaching methods of Physical Science but they concentrated more on the content itself, how you should approach several topics, but not how to talk to learners”.

The responses revealed that Eino and Helena were trained at the university on how to use the verbal mode in science classrooms, but Eino indicated that the training was minimal. The training on how teachers should talk in the classroom needs more attention in pre-training for science teachers. It can “empower science teachers to bridge the gap between the discourse of science and students' language resources” (Hanrahan, 2006, p. 32). Considering Vygotsky's view about teachers' verbal mode, the lack of training on how teachers use the verbal mode in science classrooms needs to be addressed. According to Vygotsky's social constructivism, discussed in Chapter Three, a teacher as the more knowledgeable person in a science classroom plays a key role in mediating existing scientific knowledge to learners through the verbal mode (Viiri & Saari, 2006; Vygotsky, 1978). In other words, the role of the teacher, involves the effective use of verbal communication for enabling students to make meaning of science. Similarly, Viiri and Saari (2006) note that learners' understanding is developed through the interaction between learners and their teachers, and this occurs mostly through the verbal and visual modes.

Inclusion of visual mode in science teachers' training

The results from the interviews revealed that all the teachers who participated in this study were trained at their universities regarding how to use the visual mode in science classrooms. This is important considering that the complex and interactive multimedia used in classrooms requires teachers to understand how best they can use visual mode for science teaching and learning (Cook, 2012).

Ananias pointed out videos as one of the visual representations covered during his teacher training course. He stated: *"We were taught how to use visuals especially, some videos"*. Helena indicated that she was trained about diagrams. It is crucial to include the use of videos and diagrams in science teacher training. According to Lowe (2000), in the current visually oriented age, science education relies heavily on the use of pictures and other visual resources like videos when presenting technical subject matter.

Although Eino indicated that visual literacy was part of his teacher training, he feels that its inclusion was not sufficient:

"Visuals were there from the science subjects. But from the look of things we were not really trained, we were trained on the subject content, but not on how we can present lessons. But it was there, but too little. Is just from the issue of, as, that comes with the experience over time".

The lack of inclusion of the visual mode in teachers' training is a concern elsewhere. Yeh (2010, p. 184) argues that outside of arts courses, "most students have had very little formal education in visual communication". Matusitz (2005) suggested that student teachers need to gain at least a basic understanding of how visual communication works for them to be familiar with everyday visuals in classrooms such as signs, symbols, illustrations, diagrams and graphics. In an attempt to address this issue some teacher training colleges offer courses on how various visual media work with other modes (Royce, 2002). Tertiary institutions such as

Curtin University of Technology developed courses for learning through the visual mode. Their courses were “aiming to equip teachers with a deeper understanding of the nature of visual learning while developing their capacity to develop practical teaching strategies and resources” (Lowe, 2000, p. 3).

Inclusion of verbal-visual intersemiotic complementarity in science teachers’ training

Ananias and Eino indicated that verbal-visual intersemiotic complementarity was not included in their teacher training courses. Ananias indicated that the focus at his university was only on how teachers can use the visual and verbal modes separately:

“No, we did not learn how to combine them. We were just taught them individually, how you can use visuals and how you can use verbal mode”.

Eino responded that:

“Most of those things were too little, I mean were too little though [they] were supposed to be part of it. It was not really considered during that time. Much [of] what was considered was subject content”.

The responses correspond with Royce’s (2007) findings that much work has been done on verbal language in classroom communication, and on the importance of the visual mode in classrooms. Royce (2007) further argues that little work is done on the actual nature of how the verbal and visual modes can be combined to work together to communicate meaning, and how to make multimodal science discourse visually–verbally coherent. Royce (2002) notes that how teachers are educated plays a role in promoting multimodal communication in their classrooms. If teachers are not trained on how to integrate the verbal and visual modes, their verbal-visual intersemiotic complementarity in classroom practice is also likely to be limited.

Helena's responses revealed that her teacher training did cover how to integrate the verbal and visual modes in science classrooms. Although she indicated that she was taught how to use verbal-visual intersemiotic complementarity to produce a coherent text, the results from the lesson observations revealed that she seldom integrated the verbal and visual modes compared to the other two teachers (see Figure 12).

Multimodal communications are published to stimulate the investment in teachers' education in terms of how best to develop multimodal and intersemiotic communicative competence (Royce, 2002). Despite this, some teachers still rely on their experiences when it comes to the use of verbal-visual intersemiotic complementarity in classroom. For example, Eino indicated that since he was not taught how to integrate the verbal and visual modes, he finds his own way to produce a verbal-visual coherent text. He said: *"In most of the time you will find your own way on how to 'manoeuvre' the situation and make those kids understand and how you are going to present that lesson"*. This is supported by Bambaeroo and Shokrpour (2017) who understand that experienced teachers can identify and use more interesting methods to communicate.

There are many possible reasons for differences among the teachers' responses on how verbal mode, visual mode, and verbal-visual intersemiotic complementarity was included in their training. The three teachers studied at different times, and as such, there is a possibility that the curriculum changed. Another reason is possibly that the timeframe between the year in which this study was conducted and the years some teachers left training. There is a possibility that teachers who completed training more than ten years ago have forgotten some of content of their teacher training course compared to the teachers who left the university less than a year ago. The other possible reason is that the teachers were trained at different institutions. What is covered at one institution may not be covered at the others. Furthermore, although the study involved qualified teachers, the teachers have slightly different qualifications. This might also have influenced the teachers' responses.

3. Potential uses of the verbal and visual modes

Apart from the verbal mode and the visual mode used by the teachers in their lessons, there were also other potential uses of the verbal and visual modes that the participant teachers did not make use of. The number of such instances is shown in Figure 13.

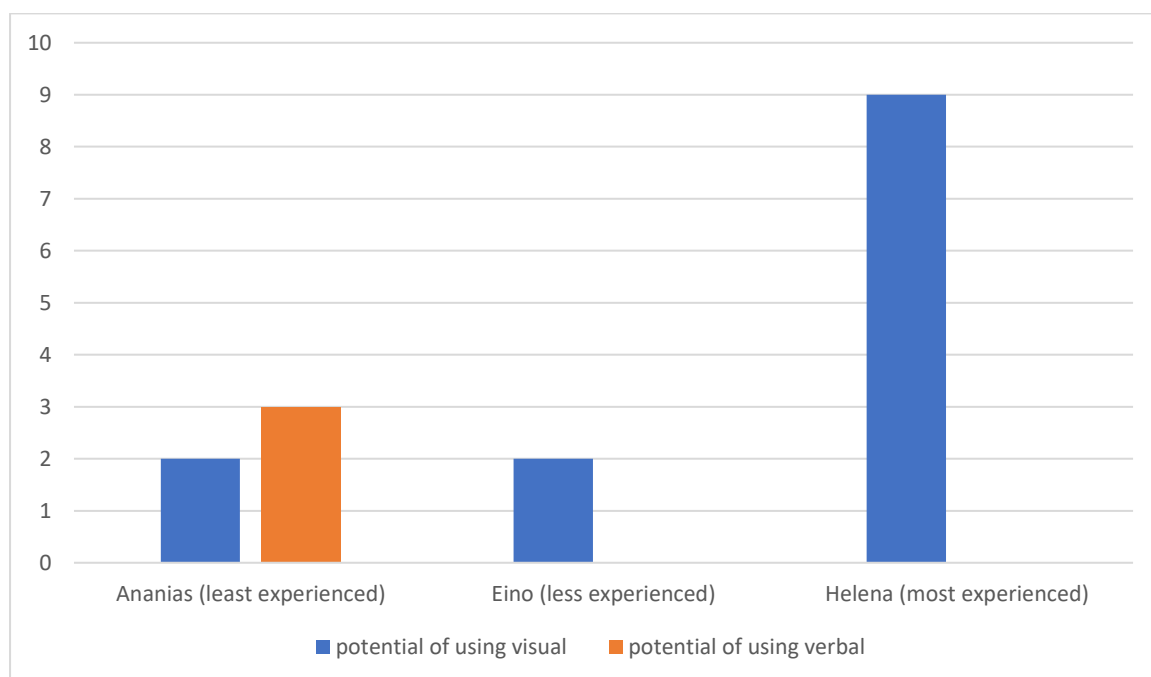


Figure 13: Potential uses of the verbal and visual modes

The results presented in Figure 13 indicate that only the least experienced teacher, Ananias had potential uses of the verbal mode but he did not use it. That shows that there is a possibility that as teachers get more experienced, their use of verbal mode in relation to visual mode also increase. Instances of potential uses of the verbal mode in Ananias' lessons included a situation where he used a visual showing different kinds of atoms. In that instance he did not use the verbal mode indicating which of the atoms represents an element, and what the other atoms represented. The verbal mode on that could have helped learners to understand and differentiate an element from other substances.

There is a balance on the potential uses of the visual mode between the least experienced teacher and the intermediate experienced teacher. The most experienced teacher who, as

discussed in previous sections of this Chapter, seldom used the intersemiotic complementarity of the visual and verbal modes, had many potential instances of use for the visual mode compared to the other two teachers. Her lack of using verbal-visual intersemiotic complementarity is not only caused by the differences in the topics taught by the teachers as suggested before, but also due to her not using the visual mode when it had potential use. Examples of potential uses of the verbal mode and visual mode that the participant teachers did not make use of it is shown in Table 27.

Table 27: Examples of potential uses of the verbal and visual modes

Teacher	Verbal mode	Potential uses of visual mode
Ananias	A teacher used a verbal mode referring to the process involved in the generation of electricity.	A teacher could have used a visual showing how the water turns the turbines, which will turn the generator to generate electricity.
Eino	A teacher used a verbal mode saying current is the same at any point in a series circuit.	A teacher could have used a visual showing ammeters connected at different points in a circuit having the same readings.
Helena	A teacher used a verbal mode referring to the uses of mercury.	A teacher could have used a visual having a picture of a thermometer.

In the examples given in Table 27, if the teachers could have used the visual mode to supplement their verbal explanations, learners might understand better. In Ananias' third lesson, he was explaining the conversion of energy in hydroelectric power stations. Ananias did not use a visual resembling the power station. This made it difficult for learners to conceptualise the process, and understand the conversions of energy involved since many learners may not ever have seen such power stations before. It would have been helpful if the teacher used a visual showing how the water turns the turbines which turn the generator, in order to produce electricity.

In Eino's third lesson, he was making the point that current is the same at any point in a series circuit. Eino did not use a visual to help learners to understand that point. It would be useful to have a visual showing a number of ammeters connected at different points in a series circuit

having the same readings. That could enhance the number of routes for retrieval and lead to enhancement of memory as proposed by McCabe (2014).

The last example in Table 27 is taken from Helena's fourth lesson. Helena was teaching about the uses of different metals. She stated that mercury is used in thermometers, without providing a visual to show to learners. If she could not find a thermometer to bring along to the class, then she could have used a visual to show to learners which type of thermometer has mercury and which substance in the thermometer is mercury.

5.6. Chapter summary

In this Chapter, I presented, analysed and discussed the data that I gathered using lesson observations and semi-structured interviews. The results showed that teachers have different perceptions about the processes involved in lesson preparation. None of the teachers mentioned that they include visual mode in their lesson planning. The results further revealed that there are no guidelines or a national policy on verbal-visual intersemiotic complementarity in school classroom. In the absence of a guideline or national policy on the use of verbal-visual intersemiotic complementarity in Namibian schools, teachers' use of verbal-visual intersemiotic complementarity depends on their subject knowledge, teacher training and their perspectives.

The results from lesson observations showed that the teachers' verbal-visual intersemiotic complementarity is aligned to the practice of intersemiotic complementarity discussed in Chapters 2 and 3. In some of the teachers' lessons all five intersemiotic sense relations were observed. The teachers also demonstrated in the interviews how they can use each intersemiotic sense relation in their Physical Science lessons. The results showed that there are no correspondences between the verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience. There is no trend found between the teachers use of verbal-visual intersemiotic complementarity and their years of science teaching experience. The intersemiotic complementarity instances identified in this

study was found to focus on mediating the understanding of physical material, processes, symbolism or resemblance.

In the additional results, the teachers indicated that the visual mode is important in a Physical Science classroom. The teachers use the visual mode to emphasises important points and to attract learners' attention. The results also showed that the teachers are not adequately or directly trained in verbal-visual intersemiotic complementarity. The additional results further revealed that there were some instances where the teachers had potential uses of the verbal mode or the visual mode.

In Chapter 6, I present the conclusions drawn from this study, some recommendations and limitations.

CHAPTER SIX: SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1. Introduction

Studies have shown that verbal-visual intersemiotic complementarity can be used by teachers in classrooms to communicate meanings or ideas that cannot be communicated better by just one mode (Royce, 2007). Research also shows that teachers' experiences influence their cognition regarding, and uses of, the visual mode (Hogan, Rabinowitz & Craven, 2003). It is possible that teachers gain more knowledge about classroom problems and events as they gain more teaching experience, which drives their understanding of the importance of semiotic modes to complement the verbal mode in the classroom (Wolff, et al., 2016). However, no research was previously undertaken to explore whether this is also true for school science in Namibia. The poor performance of Namibian science learners coupled with the challenges they face in making meaning of the multimodal discourse of science, highlighted the research gap as problematic and provided a string rationale for the study reported on in this thesis.

The aim of this study was to explore the dynamics of verbal-visual intersemiotic complementarity in the classroom practice of three Namibian Junior Secondary Physical Science teachers with different numbers of years of science teaching experience. I employed social constructivism as the theoretical framework and systemic functional linguistics (SFL) as the analytical framework due to their complimentary nature and usefulness for the research topic. A qualitative case study methodology was used to explore how Namibian Physical Science teachers use verbal-visual intersemiotic complementarity in their lessons, and identify possible correspondences between verbal-visual intersemiotic complementarity in science classroom pedagogy, and the number of years of science teaching experience.

In this final Chapter of the thesis, I present a summary of the overall findings of the study and provide some recommendations and suggestions for further research. I also highlight the limitations of the study before the thesis conclusion.

6.2. Summary of findings

The lesson observation and semi-structured interview data collected was analysed in order to answer the two research questions. The summary of the findings will now be presented in relation to these research questions.

Research Question 1:

How do the Namibian Physical Science teachers' use verbal-visual intersemiotic complementarity in their lessons?

In response to research question one, the results presented in Chapter Five (section 5.3 and section 5.4) provide insight into the three participant teachers' use of verbal-visual intersemiotic complementarity in their Physical Sciences classroom pedagogy. None of the teachers mentioned that they consider the use of the visual mode in their lesson planning. In the absence of a guideline or a national policy on the use of verbal-visual intersemiotic complementarity in Namibian schools, teachers' use of verbal-visual intersemiotic complementarity depends on the teachers' subject knowledge, teacher training and their perspectives. The results indicated that the Namibian science teachers' pedagogy is aligned to various aspects of intersemiotic complementarity. The teachers used all five intersemiotic sense relations to mediate sense making by learners in their science lessons.

However, they do not use all the sense relations in every lesson. This may be attributed to the nature of the topic or the kind of visuals they chose. It became evident that the teachers used some intersemiotic sense relations more often than others. This reveals that some intersemiotic sense relations may be (perceived as) more applicable by science teachers than others – for example, intersemiotic repetition occurred more frequently than intersemiotic antonymy. Apart from antonymy, the teachers seldom employed hyponymy. The results also showed that the teachers used all categories of intersemiotic sense relations, apart from repetition's homospatiality which was not identified in any of the teachers' lessons. Apart from using all the intersemiotic sense relations, the teachers also gave other examples of in which topics they could use all the intersemiotic sense relations in Physical Science lessons. This indicates that

they can see potential uses of the verbal-visual intersemiotic complementarity beyond the lessons observed in this study

Furthermore, the results indicated that different intersemiotic sense relations serve different purposes in the science classroom. For example, intersemiotic repetition used by the teachers involved reiteration of the meaning across the verbal and visual modes in science classrooms. Intersemiotic synonymy is used to promote the relations between science terms and concepts. Intersemiotic antonymy is used to help learners to differentiate between two concepts. Intersemiotic hyponymy and intersemiotic meronymy helps the teachers to construct relationships between science concepts. When using intersemiotic hyponymy, either of the two modes can be the main class or the sub-class. The same applies to when teachers are using intersemiotic meronymy - the verbal communication can be the whole and visual mode a part of the whole, or vice versa. Apart from its possible positive impact on learners' sense making, in some cases the teachers use intersemiotic antonymy which has possible negative impact as well (such as causing confusion in learners).

It emerged that the verbal-visual intersemiotic complementarity is employed by the teachers for mediating understanding of physical material, processes, symbolism or resemblance. Most representations of physical materials by teachers were sketch drawings on the chalkboard. They were used by the teachers to help learners make connections between what new content they were learning and things that they were already familiar with. The use of verbal-visual intersemiotic complementarity for mediating understanding of processes makes it possible for science teachers to explain complex phenomena to learners. It also helped the teachers to demonstrate fundamental science processes skills. The use of verbal-visual intersemiotic complementarity for mediating understanding of resemblance is used by the teachers to introduce learners to different scientific activities and skills. It is also used to present differences in scientific concepts. The use of verbal-visual intersemiotic complementarity for mediating understanding of symbolism is used to help learners to visualise the meaning of science terminologies. It was also used to label scientific drawings in order to support sense making.

The results showed that some teachers employed few visuals in their classroom pedagogy, which limited their use of verbal-visual intersemiotic complementarity. The results revealed that this may be due to lack of specific training about the importance of the visual mode and how to meaningfully integrate verbal communication and visuals towards intersemiotic complementarity. This agrees with literature such as Lowe (2000) which indicates that training teachers on how they can use the visual mode to complement the verbal mode is beneficial to the mediation of learners' sense making by teachers.

Research Question 2:

What are the correspondences (if any) between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of science teaching experience?

In response to research question two, the results presented in Chapter Five (Section 5.3.4) revealed the teachers' use of intersemiotic complementarity in science classroom in relation to the number of years of science teaching experience. Although teachers believe that their use of the verbal and the visual mode improves as they become more experienced, the results from lesson observations indicate this is not always true. The lesson observation results indicated that the use of verbal-visual intersemiotic complementarity in the classroom pedagogy does not correspond to the number of years of science teaching experience. The teacher who worked for less than two years (Ananias – least experienced) used verbal-visual intersemiotic complementarity more often than the teacher who worked for more than ten years (Helena – most experienced). On the other hand, the teacher who worked for less than two years used intersemiotic less than the teachers who worked for seven years (Eino – intermediate experienced).

The significant difference in the use of verbal-visual intersemiotic complementarity between the most experienced teacher (Helena) and the other two teachers, as outlined in literature was unexpected. The most experienced teacher was expected to use more verbal-visual intersemiotic complementarity compared to the other two teachers. However, this could be because teachers were not observed while teaching the same topics. Some science topics (such

as matter) may necessitate teachers to complement the verbal mode with the visual mode more strongly. Another possible reason is that the least and the intermediate experienced teachers complement verbal mode with visual mode when the learners are experiencing difficulty with topic, but most experienced teachers use the visual mode less for such purposes, as purported by Baser (2013).

6.3. Recommendations

The first recommendations are based on the teacher training institutions, advisory teachers and the school curriculum.

- **Teacher training institutions curriculum**

Based on the findings of this study, it appeared that the teacher training institutions do not directly/adequately include the pedagogic use of intersemiotic complementarity in their teacher training programmes. This means that many teachers may be experiencing challenges in terms of how to effectively use different semiotic modes in the classroom. While literature (for example, Rice (2010)) suggest that teachers use of various modes may improve as they become more experienced, the results from the current study reveal that this is not (always) the case. Given the poor performance of science learners, the multimodal discourse of science and potential benefits of intersemiotic complementarity, it is critical that Namibian science teacher training programmes include the importance of intersemiotic complementarity and how science teachers can complement the verbal mode with other semiotic modes.

- **Advisory teachers**

Advisory teachers in Namibia are strongly encouraged to engage with the literature around the usefulness of and pedagogic enactment of verbal-visual intersemiotic complementarity for them to be able to offer in-service training to Physical Science teachers. This could help

practicing science teachers effectively employ verbal-visual intersemiotic complementarity in their pedagogy towards enhanced mediation of science content.

- **Namibian school curriculum**

The results have shown that the Namibian school curriculum is silent on how teachers should use verbal-visual intersemiotic complementarity in science lessons. There is little direct mention of the visual mode, and no mention of intersemiotic complementarity. Since intersemiotic complementarity has potential value for improved science education, teacher experience does not necessarily improve practice of intersemiotic complementarity and teacher training programmes currently do not cover it in their programmes, intersemiotic complementarity can be outlined in the actual school curriculum to guide current teachers.

This case study has generated ideas around further research possibilities. It would be useful to carry out further research around verbal-visual intersemiotic complementarity across different topics by the same teacher. It is possible that teachers use visuals as a supplement to the verbal mode in some topics more than in others. A further study could also be done, with the teachers having different numbers of years of teaching experience with the same topic to have a fair comparison of their verbal-visual intersemiotic complementarity practice.

It is equally important to look at how verbal-visual intersemiotic complementarity in the Physical Science classrooms improves learners' sense making of scientific concepts. Some research has extended the scope of the analysis of meaning making in a classroom (such as Kress et al., 1997; Kress et al., 1998; Waldrup et al., 2006) to embrace the visual mode in learning science. As Cook (2011) argues, the visual mode may support learners' sense making processes in science classrooms but no study could be found at this point in time, of how an intersemiotic complementarity teaching intervention in Namibian science classrooms impacts on learners' sense making of science. Furthermore, it is worth conducting a similar study across other school grades to identify if there is any relationship between how the modes are used and the grade-level.

6.4. Limitations of the study

The findings of this case study are not necessarily generalisable, neither to all science teachers in Namibia, nor to all science teachers in the Oshana Region, due to the small sample of participants involved. However, the purpose of this study was not to generalise but to explore the dynamics of verbal-visual intersemiotic complementarity in science teacher classroom practice. Furthermore, the benefits of case study such as the dynamics of verbal-visual intersemiotic complementarity in science teacher classroom practice outweigh the limitation to generalisability.

Another limitation could be that the participants are all teachers in the Oshana Region, which is also where I teach. Being observed and interviewed by a colleague in the region could have influenced their pedagogic practice and interview responses. In an attempt to minimise this, I clearly explained the aim of the research to the participants. I also set up my observation equipment in advance and carried out one lesson observation per teacher prior to the actual data collection, in order for teachers to begin acclimatising to my presence during the science lessons.

Furthermore, the teachers were not observed covering the same topic. This might have the effect on the results as there is a possibility for some topics to have more potential for the use of verbal-visual intersemiotic complementarity than others.

6.5. Concluding remarks

This study demonstrated that some of the concepts and terminology for linguistic theory and its analytical tools have the ability to be adapted to explain how semiotic modes interact. As outlined by O'toole (1995), the results revealed that the intersemiotic sense relations used by the teachers in their lessons demonstrated that the SFL model is powerful and flexible for the study of semiotic modes. In some of the teachers' lessons all five intersemiotic sense relations were observed. Furthermore, the results of this study agree with researchers such as Inyagu

(2015) who argue that some teachers neglect the use of intersemiotic complementarity in their classrooms.

The findings of this study disagree with scholars such as Cook (2006) who argues that experienced teachers are more likely to coordinate features within and across different semiotic modes towards developing an understanding of concepts. The findings showed that there is no correspondence between verbal-visual intersemiotic complementarity in classroom pedagogy, and the number of years of Physical Science teaching experience. Furthermore, even though it is widely accepted that teachers' experience influences their cognition and representation (Hogan, Rabinowitz & Craven, 2003), the results of this study are in contradiction with the above notion.

The intersemiotic complementarity instances identified in this study was found to focus on mediating the understanding of physical material, processes, symbolism and resemblance. It was also found that in the absence of guidelines on the use of verbal-visual intersemiotic complementarity in schools, teachers' use of verbal-visual intersemiotic complementarity depends on their subject knowledge, teacher training and their perspectives.

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APPENDICES

Appendix A: Lesson observation sheet

Visual resources/communication <i>Actual visual (photographs/screenshots)</i>	Verbal resource/communication <i>Actual verbal (quotations)</i>

Appendix B: Interview transcript

1. Teachers' perceptions of the process involved in lesson preparation/planning

Question	Responses	Themes
2. Could you describe for me the process involved in the preparation of the lesson, from the beginning?	IT1: Every lesson that I teach, it always starts from home. You pre-read, you take the topic that you are going to teach tomorrow, you read through it so that you understand everything to be ready learners' questions tomorrow. Then I write the lesson plan. IT2: That have to with the grade that you are going to teach. For example, if you are going to teach the grade 9s or even the grade 10, you know already that this people they have covered...what they have covered, their prior knowledge. Now you start building your lesson based on the prior knowledge of the learners they have already. Because that is will not leave in vacuum they will give you some where were you have to step on, where you have to stand on, and have a feeling that these learners that I am going to work with, this is what they know already, so I am going to continue with this. Then from there knowing the prior knowledge, once you know they prior knowledge, you even have an idea on how you are going to introduce you lesson. Do you need to make your lesson a practical lesson, for example you want bring in teaching aids that are more practical or you just want to make it an, are what? A theoretical, of which most of the time Physical Science it is non-theoretical subject, but becomes more practical subject. For example, when you are talking, for example electricity, you bring the items to the class. If you are going to introduce some of these things, kids can be able to see this is what we are doing. So, much of the lesson plan you consider the prior knowledge of the kids and from there that is where you have to build your activities, what you going to do in the class and everything.	• Pre-reading (T1). • Get ready for learners' questions (T1). • Write a lesson plan (T1). • Consider the grade (T2). • Identify learners' prior knowledge (T2). • Think about how to introduce the lesson (T2). • Decide if the lesson will be practical or not (T2, T3). • Teaching aids (T2). • Teaching and learning activities (T3). • Basic competences (T3).

	IT3: Okay! the first thing that I look at is the basic competences, what do I expect learners to know. Mostly I focus on the activities, more on practical activities, because I found out that learners they prefer things that they can see, things that they touch. Most I engage or I include practical activities in my planning.	
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2. Teachers perception about the importance of verbal, visuals, and what the use visuals in Physical Science classroom

Question	Responses	Themes
3(1). When you started teaching did think teacher talk is important in science teaching.	IT1: I really think it is important because when you are talking you explain some of the scientific terms, and learners always copies these scientific terms from you when you explain. IT2: Yeah, teachers talk is very important. Very important from the prospective that of saying it is a tone of the voice of the teacher that will make these learners likes the subject. As a science teacher, a Physical Science teacher, there no way you will be teaching or you will be talking to kids in a very, very soft way, you have to be a bit louder. You don't need to be too high, the voice doesn't need to be harsh, it needs to be clear and ensure that every learner in that class, and in every corner can hear what you are saying. So, the voice of the teacher plays a major role in the class unlike may be in the other subject, I have seen it in science perspective. You as a teacher you have to be heard by every child, tone must be clear. You should also consider how you pronounce your words, so that you don't confuse these children in the class as learners they always have that thing of saying whatever the teacher is saying is always correct. Nowadays kids the turn to make their teachers their role models. You should always consider that you tone is very clear and your pronunciation is also clear to kids so	• Verbal is important (T1, T2, T3). • Verbal help learners to understand scientific terms (T1, T2). • The tone of the teachers attracts learner's attention (T2). • Teachers' tone makes the class to be active (T2).

	they know what are talking about. And again, it is what make the class to be active you don't need to be too soft in such a way that, like some of them when it is too hot, your tone will already make you children [learners] to be very sleepy, and how will make them awake? It is only the tone, your tone should be a very clear tone, and an awaking tone to kid. IT3: Yeah, very, very important.	
3(2). What about now, is there a change in your thinking? If yes, give examples.	IT1: There is a little bit change but not much in the sense that, before I only thought that when you are talking, you concentrate more on the scientific terms. You include them as much as possible in the lesson so that learners can get to know them, but now the most important thing is the content itself. That is what I have noticed. The content is more import than just scientific words. You can use scientific language but learners do not understand, and sometimes you may not understand even the meaning yourself in much details. IT2: The more experience you gain, the more things, I mean the experienced you become, that is when you happen to see different kind of things happening. From a novice prospective, the way you started teaching you could not understand this because you are not a novice in the class. But as you become more experience, you know this is how a teacher should talk in the class, this is how a teacher should not talk in the class. And that what initially said you as a teacher in the class you should make sure that your tone is very clear to the learners. If you happen to observe to classes, one is by a novice teacher, one is taught by an experienced teacher, there is a very big difference. Seeing from how they do their things and how they talk to the	• There is charge (T1, T2, T3). • Verbal should focus more on content but not on scientific words (T1). • Teachers tone need to clear (T2, T3). • More experienced teachers are open (T2).

	children. The more experienced teacher will become even more open when it come to the kids. IT3: Yes, there is a change. Like the first year while started teaching you are gaining experience. The way you explaining things, even the voice, the more you are gaining experience the better you are becoming an, it can be voice, tone, or it can be the lesson presentation itself.	
4(1) When you started teaching did think visuals are important in science teaching.	IT1: Not really, I never thought that visuals are important because those things of teaching and things are not really available, you only use a text book. IT2: Yes, they are important. I said earlier, science is very practical lesson. IT3: Yes, very important.	• Not really important (T1). • Visuals are important (T2, T3).
4(2) What about now, is there a change in your thinking? If yes, give example.	IT1: Now after teaching for several months, I thing visuals are really important now. This is because as the curriculum is changing, more and more complex topics are being introduced, and learners need those visuals for them to...to for remembering purposes. They can remember, they learn better when they see things. IT2: Yes, there is a change, now I understand that visuals are important because they make a lesson to becomes more practical when there are visuals teaching aids. These teaching aids, kids can be able to see with their own eyes. They are able even to touch, because that make it to be more pragmatical. Making it, yeah, you try to bring nature in the classroom, and this is from a perspective way whereby learner will be able to understand that this what you are talking about, and this is how it looks like. For example, when you dealing with testing of gasses, you just not be dealing with testing and you are just	• Visuals are important (T1, T2, T3) • Visuals are important for remembering (T1) • Learners learn better by seeing (T1, T2) • Visuals make a lesson more practical (T2). • Use visuals to explain scientific terminology (T3)

	telling the kids [learners]: this is how we test hydrogen, this is we test oxygen. You need to test some of these gasses in the class, the will already make it practical. You also need give learners notes having pictures demonstrating how different gasses are tested, for children to know and see how to prepare some of these gasses in lab. And they can be able again to do their own test and verify against theoretical test which is there. IT3: There is a change, there is a big change. Especially on the terms, hmm, iyaa, the terms that was using, now I am getting more experience, I am using more visuals to explain science terminologies compared to the time when I was not experienced.	
5. Which one do you consider more important in a Physical Science classroom, verbal (teacher talk) or visuals?	IT1: I think the teacher talk is more important, but it will only be important if you integrate it with some visuals as well. IT2: The more important one is the visual. Because learners learn better by touching and seeing. A visual is something that they can be able to see, unlike when you are just telling them. There are some things which are too theoretical, something that they never saw it, they will be having a lot of imaginations of how it looks like. But once you bring it into a class as a visual, now learners can be able to create that kind of mindset or that kind of memory that will last longer in their minds. IT3: Both, both are very important.	• Verbal is important than visual (T1) • Verbal is only important when combined with visuals (T1) • Visual is important than verbal (T2). • Visuals bring reality to the classroom (T2). • Enhance long memory (T2). • Verbal and visuals are equally important.
6. What do you use visuals for?	IT1: I normally use them when I want to emphasis a very important point. Like, let me say when I teaching, for example when I am teaching that topic of bonding, I cannot just keep on telling them about elements without having something to show them that: okay this element is in group one, using the periodic table for example. Or in any other topic you need to show them, for	• Emphasis important points (T1). • Demonstrate the process (T1). • Source of teaching aids (T2). • Long term memory (T2). • Attract learners' attention (T3).

	example, you may need a picture even when you are teaching magnets for example, you may need something to present to the learners. For them to see what is happening. IT2: Visual are coming in a sources of a teaching aids. They are coming as a source of teaching with the intention to make these learners understand and not be forgetful. You just want to create that or install that kind of memory in the child's mind. That from the look of things even after a lesson this child knows how a cell for example look like, how a bulb looks like, how I can set up this kind of connection, how a voltmeter looks like, all such things. If the child has seen one in his/her life time, will not be able to forget, that have created a permanent, it can become a permanent memory in that child. IT3: For, just to attract learners' attention.	
--	--	--

3. Inclusion of verbal, visuals, and verbal-visual intersemiotic complementarity in science teachers' training

Question	Responses	Themes
7.Can you tell me about your teaching training, did you come across: 7.1. teacher-talk	IT1: Hmm, not really, but it is involved in some of the modules that we did. Just like in the sense on how to understand learners. Just there, not really how to teach, because we did teaching methods of Physical Science but they concentrate more on the content itself, how you should approach several topics, but not how to talk to learners. IT2: Hmm, it was very little. We never come across such thing. IT3: Yes, we were trained.	• Verbal is not really included (T1). • Verbal is included very little (T2). • verbal was included (T3).

7.2 visuals	IT1 Yeah, we were taught how to use visuals especially the, some videos. When you use those videos, and simulations, we were even given a website where you can get simulations that you can show to learners in different physical science topics. We were taught how to use like, five of them I thing. IT2 Yes, visuals were there from the science subjects. But from the look of things we were not really trained, we were trained on the subject content, but not on how we can present lessons. But it was there, but too little. Is just from the issue of, as, that comes with the experience time. As the more experience you become, the more you will be able to know that this is how I should say things in the class, this is how I should talk in the class. But from training that was really neglected, though it was supposed to be part of the training, but it was neglected. IT3 Yes, like, especially the diagrams that you are using. yeah, they are very important for learners.	• Visual is included (T1, T2, T3) • How to use videos (T1) • Visual training was little (T2). • How to use visuals in the classroom comes with experience (T2). • Inclusion of visuals is sufficient (T2). • How to use diagrams (T3).
7.3 how talk and visuals can work together	IT1 No, we did not learn how to combine them. We were just taught them individually, how you can use visuals and how you can use verbal. IT2 As I said, most of those things were too little, I mean were too little though were supposed to be part of it. It was not really considered during that time. Much what was considered was on subject content. Yeah, just subject knowledge. Then from there, when you know the subject knowledge, two plus one is equal to two, you go on. But on how to present this one plus two or one plus one is equal to two. In most of the time you will find your own way how	• Verbal-visual intersemiotic complementarity was not included (T1, T2). • Verbal-visual intersemiotic complementarity was not included too little (T2). • Teachers learned on their own how to use verbal-visual intersemiotic complementarity (T2).

	you make, manyuva [find a way] the situation and make these kids understand and how you are going to present that lesson. IT3 Yes, we were taught that.	• Verbal-visual intersemiotic complementarity was included (T3).
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4. Teachers' decisions towards the use of verbal, visuals and verbal-visual intersemiotic complementarity

Question	Responses	Themes
9. Did you come across a general policy (guide line) verbal and visuals integrating in the classroom? If so, what is it?	IT1: No, I have not. I have never seen one before. I only learned them when I went to university. IT2: I never come across one so far. IT3: I did not come across any if there is any, may be.	• Never see a policy on use of verbal-visuals intersemiotic complementarity (T1, T2, T3). • Learned how to use verbal and visuals the university (T1).
10. How do you decide to use certain visual, or some combination of verbal and visuals?	IT1: It mostly depends on the types of learners that I am teaching. If I see that learners understand what I am saying just from the talking explanation, sometimes I leave out the visuals. But if I see that learners do not understand very well, I will take a visual aid to explain more. My decision is influence by learners' understanding, if they don't understand, I use visuals. If they understand, I can ignore the visuals. And also, to make work easy for me sometimes because some of the processes cannot really explain them without a picture to show. IT2: Every lesson is fall within its guides lines from the syllabus. The syllabus becomes the driving tool that will tell you what these children need to understand or need to know at the end of the day. Now, once you understand what children need to know at end of the day, that is when you think out of the box now, and think of what you should bring to class, in terms of preparation. The preparation is telling you what you should bring to class in terms of visuals that will make these	• Learners' understanding (T1). • Syllabus (T2). • Experience (T2). • Learners' interest (seeing) (T3).

	learners achieve the objective that you want to achieve at the end of the day. There is no policy that tell you how to integrate the two, that is actual depends on the creativity of the teacher. IT3: First, I have realised that learners prefer something that they can see with their eyes instead of, or rather than theory. So, I use to try by all means to find either a poster or to come up with a diagram or may be in the textbook at least related to the topic that I am busy with. Yeah, just to draw learners' attention.	
11. In deciding on what will be your verbal explanation in relation to the visuals, what guidelines do you use?	IT1: The decision, okay, I have to take examples from, from, yeah, I have to take examples of different level, like the standard of the question. I start giving them the easy examples then moving on to the more complex one. For example, if I am to draw bonding, I have to make sure that I start with a group one element, then a group two element I move to group three element, then as well as the period. Period one element if a give an example of hydrogen, then I will give an example from period two, the one with two shells, then the third example from period three, so that they get to know different examples. IT2: Subject knowledge plays a major role there, as an experienced teacher, I you now already, how I will present my lesson from the experience, because you already know what this lesson says, we don't normally follow for example what is in the text book, the syllabus is what drives us. Now once the syllabus drives you, you know already that, if the syllabus is saying this, the, for example under mass and weight, children need to know 'what is mass'. They need to know what is the	• Subject knowledge (T2). • Experience (T2). • Syllabus (T2, T3).

	‘definition of mass. Now you need integrate, once you say mass is amount of matter in an object. How will the kids understand this about of ‘matter in object’, you need to bring in visuals and objects. These children they need to weight different types objects. And they need to understand that some objects are heavier than other, what they are heavier? Because they contain more amount of matter in them. So, necessarily we are saying, I am saying there, the subject knowledge is the one that plays a major role. IT3: Normally I am guided by the syllabus. The syllabus dictates what and how I should explain to learners.	
12. Which one do you decide first, the verbal and then you try to fit the visuals around it? Or is the verbal arranged around the visuals?	IT1: First, I choose the verbal explanation. Because I have to consult the syllabus, then the basic competences that those learners need to know, then from there I can decide on the type of visuals that contain all the competences that I am going to teach that day. First is the verbal, then I can look to the visual that can support what I am going to say. IT2: First, I think of the verbal explanation, because once you now understand your verbal explanation, that is when you bring in the visuals. You need to have, once you have the knowledge of what you are going to present, that I am going to present this one and this is how I am going to say about this one. That already gives you a green light of you coming in with your visuals, and what are my teaching aids I am going to bring in the class. So, the talk first. IT3: First the visual, and then I can come up with the question like: what do you see in the diagram? Just for their, to ask for their prior knowledge on what they can see on the visual.	• Verbal explanation (T1, T2). • Visuals (T3). • Find the visual that can support what support verbal (T1).

5. Teachers understanding of verbal-visual intersemiotic complementarity in Physical Science classroom

Question	Responses	Themes
8. When I observed your lessons, I saw you integrating verbal with visuals (for example....). Apart from the situations where you integrated verbal and visuals in the lesson that I observed, can you give me another example where you integrate verbal and visuals.	IT1: Okay, I think it can, when teaching for example that topic of extraction of metals in grade 10 mostly, you can use a diagram. For example, when extracting iron, you need the furnace, that instrument. Learners, if you don't have a diagram of that instrument learners will not be able to understand, because you have to talk about the cathode and anodes. So, you need to have a picture on poster where you will tell that: okay, this is, the first step happens at this particular point, and the second step happen at this other point, like that. IT2: It can be in most of the science topics. You can even start with it from the topic of scientific processes, you link it even to mass and weight, whereby, for example in, what, in scientific processes, you can talk of things like observation, as one of the scientific processes. Here we notice things around us using our senses. Now telling the kids that, for example when you are talking about the length of classroom or length of a certain object, you can tell them about a certain length, but, yet you need to confirm that, whereby now you bring in the use of visualisation. That is the visual that we are talking about there, that you have to use a certain visual to show to learners. You can also use certain instruments, we are talking about a measuring tape, then they can measure. Now they know already if I am talking about the length, that is the longest side, for example in the building. But how can I measure now the length, what unit that I use and which instrument, they already know from the visual. They know it is measuring tape, and what are units of measuring now a distance, am I going	• Extraction of metals (T1). • scientific processes (T2). • Electricity topic (T3).

	to use millimetre, centimetre, what is there now is metres. In most of the science subject there is a link between the two. There is no way you can use visuals only in the class without talking, and there no way you can be just talking in the class without integrating now the visuals, otherwise that will leave you or the children in limbo. IT3: We can also use that one in the topic 'electricity' where you come up with different diagrams to show like how bulbs or we can say electrical components are connected in series and in parallel. You can draw that on the chalkboard just to show to the learners that is how the bulbs can [be] connected parallel or series, and then it can be other electrical components.	
13.1. Give me examples where you use Repetition (verbal repeating what is in visuals or vice versa).	IT1: I think, hmm, it can be applied in bonding. you can just explain verbally first that, for example during ionic bonding, you can just talk to the learners that a non-metal will receive electrons from a metal for the atom to achieve full electrons configuration or a full outer shell. Okay, then when you are going to draw the structures again, the visual now, when you are going to draw them on the board, you are still going to talk about the same electrons, but this time you are going to point at them, so that learners will be able to see that this electrons for example has been transferred to a non-metal atom. And this time you have to be specific, because if we say sodium loss two electrons, you are saying it verbal, and again visually, learners can see that it has lost two electrons. IT2: The measuring of mass. For example, you can just explain: we measure mass as an amount of matter in an object with a scale balance. You can bring a scale balance to the class, you can measure the mass of different objects. You know now from the talk	• Bonding (T1). • measuring of mass (T2). • Drawing atomic structures (T3). • Matter (T1, T3)

	you are telling the instrument of measuring mass is so-so, this is how it is used to measure mass. But again, from the look, if you draw it on the board kids can be able to visual, and have a visual in their book, for future reference. IT3: Let me say you are drawing shells, when you say the first shell is having two electrons, learners can also see in the diagram that it is true there are two electrons. The second shell is having four electrons, then there are four electrons that learners can see in the diagram.	
13.2. Give me examples where you use Synonyms words (verbal saying a similar meaning in visual).	IT1: I think that example can be applied when you use videos for example, okay, let's say the is about bonding again. When you teaching, you can use the word ionic bonding, but you will find that in the video that we download sometimes on the internet they say is an electrovalent bonding. I think that mean the same thing but different words. So, in the picture you are having something written electrovalent, but when you are referring to learners you are saying ionic bonding. IT2: That can be applied when we are talking about the issue of resistors. If you what to calculate for example resistance in parallel. You can have visual showing resistors connected across to each other, verbally you can say resistor are connected in branches. What you trying to explain is parallel connections. You can also have visual showing bulbs, but you can verbally refer to resistors, because bulbs can also stand as a resistor because they contain their own resistance. So, verbally you are saying they are resistors, but what learners are seeing is bulbs. So, bulbs and resistors can go hand in hand.	• Bonding (T1, T3). • Resistance (T2)

	IT3: Like the topic bonding, it can be covalent bonding or ionic bonding, like we have learned that the number of electrons on the outer shell it determines the group number. Like when you are drawing for example sodium with eleven electrons the first shell will hold two electrons, and the second will hold eight and the last one, the third shell will hold one electron. So, learners will see that this one electron on the outer shell it is equal to the group number. Same apply to group two, group three to group seven.	
13.3. Give me examples where you use Antonymy – opposite words (verbal saying something opposite to visual).	IT1: That one can be used in reversible processes when, let's say changes of states, when you are teaching, okay, you may just, when you talking to don't have any diagram you just explain but when you have visual, those solid, liquid and gasses, you can, show the arrow that when you moving from solid to liquid the arrow goes like this, and when you are coming back, is the reverse process. You can have a diagram whereby you having an arrow pointing from solid to liquid, but in your explanation, you can include moving back from liquid to solid. That is opposite, and it can help learners to understand better IT2: That can be brought in by the resistance. You can have a picture of conductors having different dimensions [diameter], drawn from the smallest to the largest, and verbally explain that when the diameter of a conductor increases, the resistance will decrease. So, the two are indirect proportion IT3: No, I don't really come across to any. Okay, maybe you can use it when you dealing with resistance. What happen with resistance? The high the resistance the low the voltage.	• Change of states (T1). • Resistance (T2, T3).
13.4. Give me examples where you use Hyponymy –	IT1: I can think of the blast furnace, used in the extraction of iron. You can just have an example of a blast furnace	• Extraction of iron (T1).

General to specific or specific to general	on a poster for example, but a blast furnace used for extraction of different metals, but in your lesson, you can be specific. Let's say when extracting iron, you use this part, showing then on the poster now. We can also use it in electrons structures. Let's say you are having the electrons structure of sodium, you can verbally relate it to other atoms. IT2: Yeah, we can stills look at perspective of the alkaline metals. Alkaline metals are elements in group one. When you just say alkaline metals, you generalise everything in group one, but if you look in the periodic table, there are specific elements in that group IT3: No	• Atomic structure (T1). • Elements in the periodic table (T2).
13.5. Give me examples where you use Meronymy – Part-whole	IT1: Like an atom is made up of, I can explain that an atom is made of three particles, the protons, the electrons and the neutrons, and you can show a picture of an atom where these particles are found. I can explain, let me say water molecule. Water molecule is made up of oxygen and hydrogen atom. We can have a visual of a water molecule, and we explain verbally that it is made up oxygen and hydrogen atom. IT2: That will bring me to some other topics that are not of our level. For example, if I talk about lunar eclipse, it is the eclipse of the mon. to understand the lunar eclipse one should just thinking that it just the mon that is involved. Much of the time if you are trying to show the diagram, from the explanation you might be talking about the mon, the eclipse of the mon. Then the mon cannot be able to be seen. Understand the mon is the illuminated object, that cannot be able to produce its own light but only reflecting light from the sun. If the lights from the sun are blocked somewhere there, the moon	• Structure of an atom (T1). • Molecules (T1). • lunar eclipse (T2). • Respiratory system (T3).

	will not be able to receive it. But from the diagram prospective, we can be able to see, how the moon, the earth and the sun are arranged, and how are lights are travelling from the sun to the moon, we can be able to see the parts of it in a diagram, while verbally we can just refer it to 'lunar eclipse'. IT3: In Physical Science? What about other science subjects? Like in Life Science, there are many organ systems in the body that are working together to perform the same function, like you can have a picture of a respiratory system that composed of the heart, the blood vessels, blood components, which you can explain verbally, but they are aiming to transport oxygen in the body.	
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Appendix C: Proposal and ethical clearance approval



RHODES UNIVERSITY

Grahamstown • 6140 • South Africa

EDUCATION FACULTY • PO Box 94, Grahamstown, 6140
Tel: (046) 603 8385 / (046) 603 8393 • Fax: (046) 622 8028 • e-mail: education@ru.ac.za

PROPOSAL AND ETHICAL CLEARANCE APPROVAL

Ethical clearance number 2017.7.04.02

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

**2017.7.04 *CLASS B RESTRICTED MATTERS*
*MASTER OF EDUCATION RESEARCH PROPOSALS***

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

Tomas Nakakuma (15N8822)

Topic: Exploring Intersubjective Complementarity in three Namibian Physical Science teachers' classroom practice.

Supervisor: Mr K Jawahar

Decision: Approved

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

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

Sincerely

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

Appendix D: Informed consent letter to the teachers



RHODES UNIVERSITY

Grahamstown • 6140 • South Africa

EDUCATION DEPARTMENT

Tel: +27 (0) 46 603 8383

Fax: +27 (0) 46 622 8028

PO Box 94, Grahamstown, 6140

Enquiries: Tomas Nakakuwa
Cell number: 0812173215

Dear [REDACTED]

**Re: Request for participation in research on intersemiotic complementarity in
Physical Science teachers' classroom practice**

I am Tomas Nakakuwa, a part-time Master student at Rhodes University, South Africa and a Mathematics and Science teacher Charles Anderson School. I am hereby requesting a permission from you to be a member of my research project that I will be conducting together with Junior Secondary Physical Science teachers. The study involves observations of four lesson per teacher, and an interview.

The study will concentrate on how teachers integrate verbal language with visuals to communicate meanings to learners. The researcher will not be involved in the lesson planning, lessons will be observed in their natural way. Your role will be teaching the normal way you teach as usual, while I am observing and videotaping.

Your participation in this research study is completely voluntary and you can withdraw at any time you wish. I will ensure that your identity and views will be treated with high degree of confidentiality and anonymity, and data that will be collected will not be used for other purpose apart from this study.

If you have any question about the research, please feel free to contact me at 0812173215, nakakuwat@gmail.com, or my supervisor Mr. Kavish Jawahar at k.jawahar@ru.ac.za.

Hence, I will request you to indicate your choice by ticking [✓] in the appropriate box below.

Agree ☐ Not agree ☐ Signature:

Your cooperation will be highly appreciated

Yours Sincerely

.....
Tomas Nakakuwa
Student (Rhodes University)

Appendix E: Informed consent letter to the parents



RHODES UNIVERSITY

Grahamstown • 6140 • South Africa

EDUCATION DEPARTMENT

Tel: +27 (0) 46 603 8383

Fax: +27 (0) 46 622 8028

PO Box 94, Grahamstown, 6140

Enquiries: Tomas Nakakuwa
Cell number: 0812173215

Dear Parent/guardian

Request for participation in research on intersemiotic complementarity in Physical Science teachers' classroom practice

I am Tomas Nakakuwa, a part-time Master student at Rhodes University, South Africa and a Mathematics and Science teacher at Charles Anderson School. You are being requesting to give permission for your child to be part of the class where I am going to observe how teachers integrate verbal language and visuals when teaching Physical Science. The study will be conducted with teachers only.

The study will require lesson observations involving video recording. Four lessons will be observed in a period of about two weeks. Kindly be informed that involvement in this study is voluntary. It is therefore the right of the parent to decide whether his/her child should be part of the class where I am going to observe or not. The identity of learners will be treated with high degree of confidentiality and anonymity, and data collected will not be used for other purpose other than this study.

If you have any question about the research, please feel free to contact me at 0812173215, nakakuwat@gmail.com, or my supervisor Mr. Kavish Jawahar at k.jawahar@ru.ac.za.

Lastly, if you agree for your child to participate in this research, please complete the consent form below.

I (full name of parent/guardian), hereby confirming that I understand the content of this document and the nature of the research. I am giving permission to (name of the child) to be part of the class where the study will be conducted.

Yours Sincerely

Tomas Nakakuwa
Student (Rhodes University)

.....
Signature (Parent/guardian)

Appendix F: Informed consent letter to the Regional Director

P O Box 8817

Ongwediva

Email: nakakuwat@gmail.com

Cell: 0812173215

22 January 2018

The Director of Education

Oshana Education Directorate

Private Bag 5518

Oshakati

Dear Madam

Re: Request for permission to conduct an educational research with Physical Science teachers (Junior Secondary) at schools in Oshana region

I am Tomas Nakakuwa, a part-time Master student at Rhodes University (student no.: 15N8822), and a Mathematics and Science teacher at Charles Anderson School. I am hereby humbly requesting for permission to conduct a science education research study with teachers in Oshana region for a period of about two months (February 2018 up to March 2018). My study will involve three Physical Science teachers, which will be selected according to their teaching qualification and years of teaching experiences, and their willingness to participate in the study.

One of the aims of the Namibia Basic Education Curriculum is to enable learners to think scientifically and apply scientific knowledge in different aspects of life. This is challenging in countries like Namibia which had been linguistically isolated. Worldwide, there has been a shift from using language as the only way of communication to a multimodal view (communicating using many ways – e.g. visuals, gestures, music and so on). Science classroom itself is considered multimodal. Considering the multimodality of science discourse, teachers' ability to work across semiotic modes (eg. verbal and visuals) is critical for construction and communication of scientific knowledge, especially in communities where most learners are

learning in second language. Appropriate selection and combination of modes (verbal, visual, gesture and others) can offers a springboard to satisfy cognitive differences, as well as to achieve the aims of the Namibia Basic Education Curriculum. Thus, this study aims to explore the intersemiotic complementarity in three Namibian Physical Science teachers' classroom practice. The study is under the supervision of Mr Kavish Jawahar (Email: K.Jawahar@ru.ac.az)

I would like to assure your office that, should I be granted permission, the research ethics will apply throughout the process of the study. Identity of participants and their views will be treated with high degree of confidentiality and anonymity.

Attached is the proposal and ethical clearance approval from the Faculty of Education Higher Degrees' Committee (Rhodes University).

Thank you for your time, and your consideration in this regard will be highly appreciated.

Yours Sincerely


.....

T Nakakuwa

Student (Rhodes University)

Appendix G: Informed consent letter to the school principals



RHODES UNIVERSITY

Grahamstown • 6140 • South Africa

EDUCATION DEPARTMENT

Tel: +27 (0) 46 603 8383

Fax: +27 (0) 46 622 8028

PO Box 94, Grahamstown, 6140

Enquiries: Tomas Nakakuwa
Cell number: 0812173215

Dear Sir/Madam

**Re: Request for permission to conduct an educational research at [REDACTED]
[REDACTED] with Junior Secondary Physical Science teachers.**

I am **Tomas Nakakuwa**, a part-time Master student at **Rhodes University (student no.: 15N8822)**, and a Mathematics and Science teacher at **Charles Anderson School**. I am hereby humbly requesting for permission to conduct a **science education research study** with Physical Science teachers at [REDACTED] for a period of about two weeks. My study will involve lesson observations and interviews.

One of the aims of the Namibia Basic Education Curriculum is to enable learners to think scientifically and apply scientific knowledge in different aspects of life. This is challenging in countries like Namibia which had been linguistically isolated. Worldwide, there has been a shift from using language as the only way of communication to a multimodal view (communicating using many ways – e.g. visuals, gestures, music and so on). Science classroom itself is considered multimodal. Appropriate selection and combination of modes (verbal, visual, gesture and others) can offers a springboard to satisfy cognitive differences, as well as to achieve the aims of the Namibia Basic Education Curriculum. Thus, this study aims to **explore the intersemiotic complementarity in three Namibian Physical Science teachers' classroom practice**. The study is under the supervision of Mr Kavish Jawahar (Email: K.Jawahar@ru.ac.az).

I would like to assure your office that, should I be granted permission, the research ethics will apply throughout the process of the study. Identity of participants and their view will be treated with high degree of confidentiality and anonymity.

Thank you for your time, and your consideration in this regard will be highly appreciated.

Yours Sincerely

..........

Tomas Nakakuwa
Student (Rhodes University)

Appendix H: Turnitin report



Digital Receipt

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

The first page of your submissions is displayed below.

Submission author: tomas nakakuwa
Assignment title: January and February 2019 submis...
Submission title: Exploring Intersemiotic Complemen...
File name: 29968_tomas_nakakuwa_Exploring..
File size: 0
Page count: 137
Word count: 41,854
Character count: 229,730
Submission date: 26-Jan-2019 02:51PM (UTC+0200)
Submission ID: 1066553130

CHAPTER ONE: INTRODUCTION

1.1. Introduction

The purpose of this study was to explore the verbal-visual intersemiotic complementarity in the classroom practice of three Namibian Physical Science teachers with varying amounts of science teaching experience. In this Chapter, I introduce the study by presenting the background, and giving an overview of the language context of Namibian teachers and learners. I also looked at Physical Science in the Namibian curriculum. I then provide statement of the research problem. Thereafter, I indicate the research goal and questions, and highlight the significance of this study. An overview of the thesis' Chapters is then provided, before the chapter summary.

1.2. Background of the study

It is important to undertake a review of the overall terrain being researched in a study, in order to provide an overview of the research and set the scene for a thesis (Opoku & Ahmed, 2016). This can be achieved by considering the current literature relevant to the issue, previous studies related to it and historical context. In this section, I first show consideration of the performance of learners in science subjects, the Examiners' reports for Namibian Junior Secondary Certificate (JSC) Physical Science, as well as factors contributing to poor performance. I also describe the semiotic modes of communication, the semiotic modes in relation to the science classroom, and the verbal mode as a challenge to Namibian learners. I then look at the effect of teachers' experiences on learners' learning before I specify the focus of the study.

1.2.1. Performance of learners in science

One of the overall problems in school education is the general poor performance of many learners in science subjects globally (Ryan, 2009). More than two decades ago, Levin (1993) revealed that the majority of learners who do not do well in science, are based in developing

Appendix I: Lesson observations analytical memo for Ananias

PM – Physical material

PC – Processes

S – Symbolism

R –

Resemblance

Intersemiotic Repetition		Categories
Visual message	Verbal message	
A visual showing two circuit diagrams	A lexical item in the teacher's explanation saying referring to circuits	R
The visual showing two resistors in a series connection.	A lexical item in the teacher's explanation saying the connection is a series connection.	R
A visual showing labels R1 and R2.	A lexical item in the teacher's explanation saying the first resistor is R1, and the other is R2	S
Two symbols of resistors connected in series.	A lexical item in the teacher's explanation referring to the connection as series.	S
Two symbols of resistors connected in parallel	A lexical item in the teacher's explanation referring to the connection as parallel	S
A diagram of circuits with resistors connected in parallel.	A lexical item in the teacher's verbal refers to the type of connection as parallel	R
A visual showing a diagram of circuits with resistors connected in parallel.	A lexical item in the teacher's verbal referring to the type of connection as parallel	R
A visual showing a diagram of a resistor added to the left side of the other resistor	A lexical item in the teacher's verbal saying another resistor is added.	S
A visual showing a diagram with a resistor label R4.	A lexical item in the teacher's verbal referring to the resistor as R4.	S
A visual showing four different diagrams which can be grossed as atoms.	A lexical item in the teacher's verbal saying there are different kinds atoms.	R
A visual showing diagrams of substances made up of the one kinds of atoms which can be grossed as elements	A lexical item in the teacher's verbal saying elements are made up of one kind of atom.	R
A visual showing a diagram of atoms.	A lexical item in the teacher's verbal referring to atoms.	R
A visual showing a diagram of atoms drawn in different size and shapes.	A lexical item in the teacher's verbal saying atoms are of different kinds.	R
A visual showing a periodic table of elements having both the element names and symbols.	A lexical item in the teacher's verbal explanation referring to the names and symbols for elements.	S
A visual showing a poster of the periodic table with the title 'periodic table of the elements'.	A lexical item in the teacher's verbal explanation saying what is in the poster is called a periodic table.	R

A visual showing letters in the middle of the blocks of the periodic table.	A lexical item in the teacher's explanation saying the letter are in the middles of the blocks.	S
A visual showing letter 'B' in the periodic table with the name Boron written below the letter.	A lexical item in the teacher's verbal explanation saying the letter 'B' for Boron.	S
A visual showing an atomic structure of an element having 8 electrons.	A lexical item in the teacher's verbal explanation saying the electrons are 8.	R
A visual showing an atomic structure with electrons on the shells.	A lexical item in the teacher's verbal explanation saying the electrons are found on shells.	R
A visual showing crosses drawn on circles.	A lexical item in the teacher's verbal referring crosses.	S
A visual showing a picture of an atom with electrons drawn on shells.	A lexical item in the teacher's verbal saying electrons are found in shells.	R
A visual indicating that protons and neutrons are found in the nucleus.	A lexical item in the teacher's verbal saying protons are neutrons are found in the nucleus.	S
A visual showing horizontal columns in a periodic table representing periods.	A lexical item in the teacher's verbal saying periods are horizontal columns of the periodic table.	R
A visual showing a picture of the periodic table.	A lexical item in the teacher's verbal referring the periodic table	R
A visual showing numbers on the left side of the periodic table representing period numbers.	A lexical item in the teacher's verbal saying the number represents periods.	S
A visual showing calcium in period four.	A lexical item in the teacher's verbal saying calcium is in period four.	S
A visual showing hydrogen in period one in the periodic table.	A lexical item in the teacher's verbal saying hydrogen is in period one.	S
A visual showing a hydrogen atomic structure having one shell.	A lexical item in the teacher's verbal saying hydrogen has only one shell.	R
A visual showing a line drawn from the center of the atom, with the number of protons and neutrons indicated at the end of the line.	A lexical item in the teacher's verbal saying to arrow represents the number protons and the number of neutrons	S
A visual showing a line drawn from the center.	A lexical item in the teacher's verbal saying the arrow is always drawn from the center.	S
A visual showing hydrogen atom having one proton.	A lexical item in the teacher's verbal saying the number of protons of hydrogen is one.	S
A visual showing hydrogen atom having zero neutrons.	A lexical item in the teacher's verbal saying hydrogen has zero neutrons.	S
A visual showing two structures of hydrogen atoms, one drawn with an electron denoted by a cross, and another with a dot.	A lexical item in the teacher's verbal saying electrons can either be indicated with crosses or dots.	R

A visual showing hydrogen in period one of the periodic table.	A lexical item in the teacher's verbal saying hydrogen is in period one.	S
A visual showing hydrogen in group one of the periodic table.	A lexical item in the teacher's verbal saying hydrogen is in group one.	S
A visual showing a structure of oxygen atom.	A lexical item in the teacher's verbal saying the picture is a structure of oxygen atom.	R
A visual showing a periodic table having all mass number large than protons number.	A lexical item in the teacher's verbal saying protons number is always the smaller number in every atom.	R
A visual showing a structure of oxygen atom with eight protons.	A lexical item in the teacher's verbal saying oxygen has eight protons.	R
A visual showing a Bohr structure of oxygen atom.	A lexical item in the teacher's verbal referring the picture to the Bohr structure of oxygen.	R
A visual showing a structure of oxygen atom having eight electrons.	A lexical item in the teacher's verbal saying oxygen has eight electrons.	R
A visual showing a structure of oxygen atom having eight electrons in shells.	A lexical item in the teacher's verbal saying electrons are the one should be indicated in shells.	R
A visual showing a structure of oxygen atom having two shells.	A lexical item in the teacher's verbal saying oxygen has two shells.	R
A visual showing a structure of oxygen atom having only two electrons on the first shell.	A lexical item in the teacher's verbal saying the first shell of an atom can only take up to two electrons.	R
A visual showing a structure of oxygen atom having eight protons indicated.	A lexical item in the teacher's verbal saying the eight protons should be indicated.	R
A visual showing a structure of oxygen atom having eight neutrons indicated.	A lexical item in the teacher's verbal saying oxygen has eight neutrons.	R
A visual showing of an arrow showing a conversion of energy.	A lexical item in the teacher's verbal saying the water is converted into kinetic energy.	S
A visual showing energy conversion from gravitational potential energy to kinetic energy, then from kinetic energy to electric energy.	lexical items in the teacher's verbal saying gravitational potential energy is converted to kinetic energy, and the kinetic energy is converted to electric energy.	PC
A visual showing a structure of chlorine atom having three shells.	A lexical item in the teacher's verbal saying chlorine has three shells.	R
A visual showing a picture of a periodic table with chlorine having seventeen protons.	A lexical item in the teacher's verbal saying chlorine has seventeen protons.	S
A visual showing a structure of chlorine atom having two electrons on the first shell.	A lexical item in the teacher's verbal saying the first shell can only take a maximum of two electrons.	R

A visual showing a structure of chlorine atom having eight electrons on the second shell.	A lexical item in the teacher's verbal saying the second shell can only take a maximum of eight electrons.	R
A visual showing a structure of chlorine atom having seven electrons on the outer shell.	A lexical item in the teacher's verbal saying the outer shell of chlorine atom has seven electrons.	R
A visual showing a structure of chlorine atom with seventeen protons and eighteen-point-five neutrons indicated that they are in the nucleus.	A lexical item in the teacher's verbal saying there are seventeen protons and eighteen-point-five neutrons in the nucleus of chlorine atom.	R
A visual showing a picture of a windmill.	A lexical item in the teacher's verbal referring to a windmill.	PM
A visual showing a phrase 'kinetic energy'.	A lexical item in the teacher's verbal referring to kinetic energy.	S
A visual showing a phrase 'electrical energy'.	A lexical item in the teacher's verbal referring to electrical energy.	S
A visual showing an arrow of energy conversion from one form of energy to another	A lexical item in the teacher's verbal saying energy is converted from one form to another.	S

Intersemiotic Synonymy		Categories
Visual message	Verbal message	
A visual showing a periodic table having rows.	A lexical item in the teacher's verbal referring to periods.	R
A visual showing a periodic table with chlorine in the third row.	A lexical item in the teacher's verbal saying chlorine is in period three.	S
A visual showing a picture of a periodic table with chlorine in period three.	A lexical item in the teacher's verbal saying chlorine atom is having three shells.	S
A visual showing a structure of chlorine atom having seventeen protons and seventeen electrons.	A lexical item in the teacher's verbal saying the number of protons and electrons are equal.	R
A visual showing a picture of a periodic table with chlorine having seventeen protons.	A lexical item in the teacher's verbal saying chlorine has seventeen electrons.	S
A visual showing a structure of chlorine atom having three shells.	A lexical item in the teacher's verbal saying chlorine is in period three.	R
A visual showing a structure of chlorine atom having seven electrons on the outer shell.	A lexical item in the teacher's verbal saying chlorine is in group seven.	R
A visual showing a rectangular shape electric symbol.	A lexical item in the teacher's explanation saying the symbol is a resistor.	S
A visual showing an electric symbol of a circular shape with a cross inside.	A lexical item in the teacher's explanation saying the symbol is a bulb.	S
A visual showing rectangular shape electric symbol.	A verbal message saying the symbol is a resistor.	S

A visual showing two circuit diagrams, the first with two resistors and the second with three resistors.	A lexical item in the teacher's verbal saying the number of resistors increase.	R
A visual showing a rectangular shape of an electric symbol.	A verbal message saying the symbol is a resistor.	S
A visual showing substance represented by diagrams in form of squares.	A lexical item in the teacher's verbal referring to blocks.	R
A visual showing diagram of two blocks.	A lexical item in the teacher's verbal referring to substances.	R
A visual showing a diagram of atoms which looks alike.	A lexical item in the teacher's verbal saying the atoms are similar.	R
A visual showing a diagram of atoms which looks alike.	A lexical item in the teacher's verbal saying the atoms are of the same kind.	R
A visual showing names and symbols of elements in the periodic table arranged according to the numbers written on the top right corner.	A lexical item in the teacher's verbal explanation saying elements are arranged according to their atomic numbers.	S
A visual showing letters in the periodic table.	A lexical item in the teacher's verbal explanation saying letters are symbols of elements.	S
A visual showing sodium in the periodic table with a symbol Na	A verbal item in the teacher's verbal explanation saying the symbol of an element have nothing to do with the name.	S
A visual showing a periodic table having vertical columns.	A verbal item in the teacher's verbal explanation referring groups.	R
A visual showing a periodic table having horizontal rows.	A verbal item in the teacher's verbal explanation referring periods.	R
A visual showing helium in the first row of the periodic table.	A verbal item in the teacher's verbal explanation saying helium is in period one.	S
A visual showing an atomic structure having 8 protons and 8 electrons.	A lexical item in the teacher's verbal explanation saying the number of protons and electrons are equal.	R
A visual showing an atomic structure with electrons on the shells.	A lexical item in the teacher's verbal explanation saying the electrons orbits the nucleus.	R
A visual showing a picture drawn with two circles and crosses on circles.	A lexical item in the teacher's verbal referring to an atom.	R
A visual showing crosses drawn on circles.	A lexical item in the teacher's verbal referring to electrons	R
A visual showing horizontal columns in a periodic table.	A lexical item in the teacher's verbal referring the columns to periods.	R
A visual showing a hydrogen atomic structure having one shell.	A lexical item in the teacher's verbal saying hydrogen is in period one.	R

A visual showing an atom with one electron and one proton.	A lexical item in the teacher's verbal saying the number of electrons is equal to the number of protons	R
A visual showing a periodic table drawn with vertical columns.	A lexical item in the teacher's verbal referring to groups.	R
A visual showing a structure of atom with one shell.	A lexical item in the teacher's verbal saying the element is in period one.	R
A visual showing a structure of atom with one electron on the outer shell.	A lexical item in the teacher's verbal saying the element is in group one.	R
a visual showing hydrogen in group one of the periodic table.	A lexical item in the teacher's verbal saying hydrogen has one electron on the outer shell.	R
A visual showing hydrogen in period one of the periodic table.	A lexical item in the teacher's verbal saying hydrogen has one shell.	R
A visual showing a structure of oxygen atom having electrons draw in shells and protons indicated that they are at the center.	A lexical item in the teacher's verbal saying what in the shells is not protons but is electrons.	R
A picture showing a structure of oxygen atom having two shells.	A lexical item in the teacher's verbal saying oxygen is in period two.	R
A visual show a structure of oxygen atom having eight protons and eight electrons.	A lexical item in the teacher's verbal saying the number of protons is equal to the number of electrons.	R
A visual showing a structure of oxygen atom having six electrons on the second shell.	A lexical item in the teacher's verbal saying the second shell of oxygen can take up all the remaining electrons.	R
A visual showing a structure of oxygen atom having eight neutrons.	A lexical item in the teacher's verbal saying the number of neutrons is mass number minus protons number.	R
A visual showing an arrow pointing from gravitational potential energy to kinetic energy.	A lexical item in the teacher's verbal saying gravitational potential energy in water is converted to kinetic energy.	PM
A visual showing an arrow pointing from kinetic energy to electrical energy.	A lexical item in the teacher's verbal saying kinetic energy is being converted to electrical energy.	PM
A visual showing an arrow of energy conversion from one form of energy to another.	A lexical item in the teacher's verbal saying energy is not created.	PM

Intersemiotic Antonymy		Categories
Visual message	Verbal message	
A visual showing a series connection.	A lexical item in the teacher's explanation referring to parallel connection.	R
A visual showing a parallel connection.	A lexical item in the teacher's explanation saying the previous circuit is a series.	R

A visual of a diagram showing an increase in the number of resistors.	A lexical item in the teacher's verbal saying the total resistance decreases	R
A visual showing a diagram of a substance made up of different kinds atoms.	A lexical item in the teacher's verbal saying an element is only made up of one kind of atom.	R
A visual showing a picture of elements in the periodic table with their names started with the letters of their symbols.	A lexical item in the teacher's explanation saying the symbol does not mean the element's name start with the that letter.	S
A visual showing a line drawn without an arrowhead.	A lexical item in the teacher's verbal referring to an arrow.	S
A visual showing a structure of hydrogen atom.	A lexical item in the teacher's verbal referring to oxygen.	R
A visual showing a picture of a windmill without a generator.	A lexical item in the teacher's verbal saying the turbine turns the generators.	PM
A visual showing a picture of a periodic table with the protons number of oxygen indicated.	A lexical item in the teacher's verbal referring to electrons.	R
A visual showing oxygen having a mass number of 15.999.	A lexical item in the teacher's verbal saying the mass number of oxygen is 16.	S
A visual showing an atomic structure.	A lexical item in the teacher's verbal referring the diagram to an element.	R
A visual showing a line drawn from the nucleus without an arrowhead.	A lexical item in the teacher's verbal referring to an arrow.	S
A visual showing an atomic structure of an element drawn without a center indicated.	A lexical item in the teacher's verbal referring to the center.	R
A visual showing a diagram of a substance made up of different kinds atoms	A lexical item in the teacher's verbal saying an element is only made up of one kind of atom.	R

Intersemiotic Hyponymy		Category
Visual message	Verbal message	
A visual showing a diagram of an electric circuit – general class.	A lexical item in the teacher's explanation saying the connection of the circuit is series connection – sub-class.	R
A visual showing a diagram of an electric circuit – general class.	A lexical item in the teacher's explanation saying the connection of the circuit is parallel connection – sub-class.	R
A visual showing a diagram with electric symbols – general class.	A lexical item in the teacher's explanation referring to the symbols as resistors and a bulb – sub-class.	S

A visual showing a diagram of an electric circuit – general class.	A lexical item in the teacher's explanation that refers to the type of connection of the circuit as parallel connection – sub-class.	R
A visual showing a diagram of resistors connected in two different types of connections – general class.	A lexical item in the teacher's explanation that referring to one of the connections as parallel – sub-class.	R
A visual showing a diagram of resistors connected in two different types of connections – general class.	A lexical item in the teacher's explanation referring to one of the connections as series – sub-class.	R
A visual showing diagrams of specific atoms – sub-class.	A lexical item in the teacher's verbal saying there are different kinds of atoms – general class.	R
A visual showing a diagram of an element – sub-class.	A lexical item in the teacher's verbal explaining referring to substances – general class.	R
A visual showing the periodic table – general class.	A lexical item in the teacher's verbal referring to element – sub-class	R
A visual showing a poster of elements in the periodic table – general class.	A lexical item in the teacher's verbal referring to sodium – sub-class	R
A visual showing the periodic table – general class.	A lexical item in the teacher's verbal referring to helium – sub-class	R
A visual showing an atomic structure of an element – general class.	A lexical item in the teacher's verbal referring to oxygen – sub-class.	R
A visual showing a picture of an atom – general class.	A lexical item in the teacher's verbal referring a diagram to oxygen atom – sub-class.	R
A visual showing periods in a periodic table – general class.	A lexical item in the teacher's verbal referring to elements – sub-class.	R
A visual showing period one in a periodic table – general class.	A lexical item in the teacher's verbal referring to hydrogen – sub-class.	R
A visual showing a periodic table – general class.	A lexical item in the teacher's verbal referring to hydrogen – sub-class.	R
A visual showing period one in a periodic table – general class.	A lexical item in the teacher's verbal referring to hydrogen – sub-class.	R
A visual showing group one in a periodic table – general class.	A lexical item in the teacher's verbal referring to hydrogen – sub-class.	R
A visual showing periods of the periodic table – whole.	A lexical item in the teacher's verbal referring to period one – part of the whole.	R
A visual showing groups of the periodic table – whole.	A lexical item in the teacher's verbal referring to group one – part of the whole.	R
A visual showing a picture of a periodic table – general class.	A lexical item in the teacher's verbal referring to oxygen – sub-class.	R
A visual showing a picture of a periodic table – general class.	A lexical item in the teacher's verbal referring to chlorine – sub-class.	R

A visual showing a phrase 'gravitational potential energy' – sub-class.	A lexical item in the teacher's verbal saying potential energy – general class	S
A visual showing a phrase 'gravitational potential energy' – general class.	A lexical item in the teacher's verbal referring to water falling – sub-class	S

Intersemiotic Meronymy		Category
Visual message	Verbal message	
A circuit diagram drawn with electric symbols – whole.	A lexical item in the teacher's explanation referring to a resistor – part of the whole.	R
A circuit diagram drawn with electric symbols – whole.	A lexical item in the teacher's explanation referring to a bulb – part of the whole.	R
A visual showing resistance of specific resistors – part of the whole.	Lexical items in the teacher's explanation referring to the total resistance of a circuit – whole.	S
A circuit diagram drawn with electric symbols – whole.	A lexical item in the teacher's explanation referring to a resistor – part of the whole.	R
A visual showing a diagram of resistors connected in a circuit – whole.	Lexical items in the teacher's explanation saying a certain resistor is connected in series – part of the whole.	R
A visual of a diagram showing resistance of specific resistors – part of the whole.	A lexical item in the teacher's explanation saying the total resistance in the circuit can be obtained by adding the resistance of all resistors – whole.	S
A visual showing diagrams of atoms – part of the whole.	A lexical item in the teacher's verbal explaining that an element is a substance made up of atoms – whole.	R
A visual showing a diagram of an atoms – part of the whole.	A lexical item in the teacher's verbal explaining referring to a substance – whole.	R
A visual showing a diagram of atoms – part of the whole.	A lexical item in the teacher's verbal explaining referring to an element – whole.	R
A visual showing a periodic table – whole.	A lexical item in the teacher's verbal referring to periods – part of the whole.	R
A visual showing a periodic table – whole.	A lexical item in the teacher's verbal referring to groups – part of the whole.	R
A visual showing an atomic structure of an element – whole.	A lexical item in the teacher's verbal referring to electrons – part of the whole.	R

A visual showing an atomic structure of an element – whole.	A lexical item in the teacher's verbal referring to protons – part of the whole.	R
A visual showing an atomic structure of an element – whole.	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	R
A visual showing an atomic structure of an element – whole.	A lexical item in the teacher's verbal referring to a nucleus – part of the whole.	R
A visual showing an atomic structure of an element – whole.	A lexical item in the teacher's verbal referring to shells – part of the whole.	R
A visual showing shells in atomic structure of an element – whole.	A lexical item in the teacher's verbal referring to electrons – part of the whole.	R
A visual showing a picture of oxygen atom – part of the whole.	A lexical item in the teacher's verbal referring to oxygen – whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher's verbal referring to electrons – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher's verbal referring to shells – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher's verbal referring to nucleus – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher's verbal referring to protons – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	R
A visual showing shells – whole.	A lexical item in the teacher's verbal referring to electrons – part of the whole.	R
A visual showing a nucleus – whole.	A lexical item in the teacher's verbal referring to protons – part of the whole.	R
A visual showing a nucleus – whole.	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	R
A visual showing period one of the periodic table – whole.	A lexical item in the teacher's verbal referring to hydrogen and helium – part of the whole.	R
A visual showing an atomic structure of hydrogen – whole.	A lexical item in the teacher's verbal referring to electrons – part of the whole.	R
A visual showing hydrogen in the periodic table – whole	A lexical item in the teacher's verbal referring to protons – part of the whole.	R

A visual showing hydrogen in the periodic table – whole	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	R
A visual showing the mass number of hydrogen – whole.	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	S
A visual showing a structure of an atom – general class	A lexical item in the teacher's verbal referring to the outer shell – part of the whole.	R
A visual showing a structure of an atom – whole.	A lexical item in the teacher's verbal referring to electrons on outer shell – part of the whole.	R
A visual showing a picture of a periodic table – whole.	A lexical item in the teacher's verbal referring to protons – part of the whole.	R
A visual showing a picture of a periodic table – whole.	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to protons – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to electrons – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to neutron – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to shells – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to first shell – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to second shell – part of the whole.	R
A visual showing a picture of a periodic table – whole.	A lexical item in the teacher's verbal referring to periods – part of the whole.	R
A visual showing a structure of chlorine atom – whole.	A lexical item in the teacher's verbal referring to shells – part of the whole.	R
A visual showing chlorine in the periodic table – whole.	A lexical item in the teacher's verbal referring to number of protons of chlorine – part of the whole.	R
A visual showing a structure of chlorine atom – whole.	A lexical item in the teacher's verbal referring to the first shell – part of the whole.	R
A visual showing a structure of chlorine atom – whole.	A lexical item in the teacher's verbal referring to the second shell – part of the whole.	R

A visual showing a structure of chlorine atom – whole.	A lexical item in the teacher's verbal referring to the third shell – part of the whole.	R
A visual showing a structure of chlorine atom – whole.	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	R
A visual showing a structure of chlorine atom – whole.	A lexical item in the teacher's verbal referring to the nucleus – part of the whole.	R
A visual showing the mass number chlorine in the periodic table – whole.	A lexical item in the teacher's verbal referring to neutrons number – part of the whole.	S
A visual showing the mass number chlorine in the periodic table – whole.	A lexical item in the teacher's verbal referring to protons number – part of the whole.	S
A visual showing a picture of a windmill – whole.	A lexical item in the teacher's verbal referring to a turbine – part of the whole.	PM
A visual showing a picture of a windmill – whole.	A lexical item in the teacher's verbal referring to a blade – part of the whole.	PM
A visual showing a picture of a turbine – whole.	A lexical item in the teacher's verbal referring to a blade – part of the whole.	PM
A visual showing a picture of a turbine – part of a whole	A lexical item in the teacher's verbal referring to a generator – whole.	PM
A visual showing a picture of a periodic table – whole.	A lexical item in the teacher's verbal referring to a period – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to shells – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to electrons – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to protons – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to neutrons – part of the whole.	R
A visual showing a structure of oxygen atom – whole.	A lexical item in the teacher's verbal referring to nucleus – part of the whole.	R

Appendix J: Lesson observation analytical memo for Eino

PM – Physical material **PC** – Processes **S** – Symbolism **R** – Resemblance

Intersemiotic Repetition		Categories
Visual message	Verbal message	
A visual showing zero on a number line.	A lexical item in the teacher's verbal referring to zero.	S
A visual showing sodium atom having eleven electrons.	A lexical item in the teacher's verbal saying sodium has eleven electrons.	R
A visual showing a number line.	A lexical item in the teacher's verbal referring to a number line.	S
A visual showing a negative sign on the left-hand side of a number line.	A lexical item in the teacher's verbal saying negative numbers are on the left side of a number line.	S
A visual showing a positive on the right-hand side of a number line.	A lexical item in the teacher's verbal saying positive numbers are on the right side of a number line.	S
A visual showing eleven protons in a nucleus of sodium atom.	A lexical item in the teacher's verbal saying sodium has eleven protons.	S
A visual showing 'P' for protons in the nucleus.	A lexical item in the teacher's verbal saying protons are found in a nucleus.	S
A visual showing electrons on a shell of an atom.	A lexical item in the teacher's verbal saying electrons are found in shells.	R
A visual showing to switches.	A lexical item in the teacher's verbal referring to a switch.	S
A visual showing a symbol of an open switch.	A lexical item in the teacher's verbal referring an open circuit.	S
A visual showing a symbol of a closed switch.	A lexical item in the teacher's verbal referring a closed switch.	S
A visual showing two symbols of a bulb.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a sketch drawing of a house.	A lexical item in the teacher's verbal referring to a house.	PM
A visual showing a metal spike on top of a house.	A lexical item in the teacher's verbal referring to a metal spike.	PM
A visual showing the roof of a house.	A lexical item in the teacher's verbal referring to the roof.	PM
A visual showing circuit symbols.	A lexical item in the teacher's verbal referring to circuit symbols.	S
A visual showing a symbol of a cell.	A lexical item in the teacher's verbal referring a cell	SS
A visual showing a symbol of a conducting wire.	A lexical item in the teacher's verbal referring a connecting wire.	S
A visual showing a symbol of an ammeter.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a symbol of a voltmeter.	A lexical item in the teacher's verbal referring to a voltmeter.	S

A visual showing a symbol of an ammeter with a 'A' inside a circle.	A lexical item in the teacher's verbal saying an ammeter has a 'A' inside the circle.	S
A visual showing a symbol of a voltmeter with 'V' inside a circle.	A lexical item in the teacher's verbal saying a voltmeter has a 'V' inside the circle.	S
A visual showing a symbol of a fuse.	A lexical item in the teacher's verbal referring to a fuse.	S
A visual showing a symbol of a resistor.	A lexical item in the teacher's verbal referring to a resistor.	S
A visual showing a fuse symbol with a line in between.	A lexical item in the teacher's verbal saying a fuse has a line in between	S
A visual showing a resistor without a line in between.	A lexical item in the teacher's verbal saying a resistor does not have a line in between.	S
A visual showing a symbol of an ammeter.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a symbol of a voltmeter.	A lexical item in the teacher's verbal referring to a voltmeter.	S
A visual showing a symbol of a bulb.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a symbol of a variable resistor.	A lexical item in the teacher's verbal referring to a variable resistor.	S
A visual showing a symbol of variable resistor with crossing arrow.	A lexical item in the teacher's verbal saying a variable resistor has a crossing arrow.	S
A visual showing a symbol of an ohmmeter.	A lexical item in the teacher's verbal referring to an ohmmeter.	S
A visual showing a symbol of a bulb.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a symbol of an ammeter.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a positive sign on a long terminal.	A lexical item in the teacher's verbal saying the long terminal is positive.	S
A visual showing a negative sign on a short terminal.	A lexical item in the teacher's verbal saying the short terminal is negative.	S
A visual showing an arrow pointing from negative to positive.	A lexical item in the teacher's verbal saying electrons move from negative to positive	S
A visual showing an arrow at the negative terminal pointing up.	A lexical item in the teacher's verbal saying the arrow at the negative terminal is pointing up.	S
A visual showing an arrow at the positive terminal pointing down.	A lexical item in the teacher's verbal saying the arrow at the positive terminal is pointing down.	S
A visual showing a parallel circuit.	A lexical item in the teacher's verbal referring to a parallel circuit.	R

A visual showing a parallel circuit with components connected across each other.	A lexical item in the teacher's verbal saying components in a parallel circuit are connected across each other.	R
A visual showing a symbol of cells.	A lexical item in the teacher's verbal referring to cells.	S
A visual showing a symbol of a bulb.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a symbol of a switch.	A lexical item in the teacher's verbal referring to a switch.	S
A visual showing a symbol of a closed switch.	A lexical item in the teacher's verbal referring to a closed switch.	S
A visual showing a bulb removed.	A lexical item in the teacher's verbal referring to a removed bulb.	R
A visual showing a circuit diagram.	A lexical item in the teacher's verbal referring to a circuit.	R
A visual showing a symbol of an ammeter.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing an ammeter connected in line with a bulb.	A lexical item in the teacher's verbal saying an ammeter is connected in line.	R
A visual showing a symbol of a bulb.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a symbol of an ammeter.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing an ammeter connected next to bulb.	A lexical item in the teacher's verbal saying an ammeter is connected next to the bulb.	S
A visual showing a symbol of a voltmeter.	A lexical item in the teacher's verbal referring to a voltmeter.	S
A visual showing a voltmeter connected across a bulb.	A lexical item in the teacher's verbal saying a voltmeter is connected across a bulb.	R
A visual showing a series circuit.	A lexical item in the teacher's verbal referring to a series circuit.	R
A visual showing an ammeter labelled 1.	A lexical item in the teacher's verbal referring to ammeter one.	S
A visual showing an ammeter labelled 2.	A lexical item in the teacher's verbal referring to ammeter two.	S
A visual showing 2.5 written near ammeter 1.	A lexical item in the teacher's verbal saying the reading of ammeter 1 is having 2.5 amperes.	S
A visual showing two cells.	A lexical item in the teacher's verbal referring to two cells.	S
A visual showing three cells.	A lexical item in the teacher's verbal referring to three cells.	S
A visual showing a series circuit.	A lexical item in the teacher's verbal referring to a series circuit.	R

A visual showing a series circuit with components connected in line with each other.	A lexical item in the teacher's verbal saying components in a series circuit are connected in line with each other.	R
A visual showing a symbol of a bulb.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a symbol of an ammeter.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a symbol of a switch.	A lexical item in the teacher's verbal referring to a switch.	S
A visual showing a symbol of a closed switch.	A lexical item in the teacher's verbal referring to a closed switch.	S
A visual showing a general equation of the reaction between metals and acids.	A lexical item in the teacher's verbal referring to a general equation of the reaction between metals and acids.	PC
A visual showing a word equation with the words 'hydrochloric acid'.	A lexical item in the teacher's verbal referring hydrochloric acid.	S
A visual showing a word equation with the word 'magnesium'.	A lexical item in the teacher's verbal referring magnesium.	S
A visual showing a word equation with the words 'magnesium chloride'.	A lexical item in the teacher's verbal referring to magnesium chloride.	S
A visual showing a word equation with the words 'hydrogen gas'.	A lexical item in the teacher's verbal referring hydrogen gas.	S
A visual showing a symbol for magnesium.	A lexical item in the teacher's verbal referring magnesium.	S
A visual showing a symbol for chlorine.	A lexical item in the teacher's verbal referring chlorine.	S
A visual showing crossing of valencies.	A lexical item in the teacher's verbal referring crossing of valencies.	R
A visual showing magnesium gained one valency and chlorine gained two.	A lexical item in the teacher's verbal saying one valency goes to magnesium and two goes to chlorine.	S
A visual showing a symbol for magnesium in a magnesium chloride written without a one.	A lexical item in the teacher's verbal one cannot be written down.	S
A visual showing a word equation with the word 'sulfuric acid'.	A lexical item in the teacher's verbal referring sulfuric acid.	S
A visual showing a word equation with the word 'lithium'.	A lexical item in the teacher's verbal referring lithium.	S
A visual showing a word equation with the word 'lithium sulfate'.	A lexical item in the teacher's verbal referring to lithium sulfate.	S
A visual showing a word equation with the word 'hydrogen gas'.	A lexical item in the teacher's verbal referring hydrogen gas.	S
A visual showing a general equation of the reaction between acid and carbonate.	A lexical item in the teacher's verbal referring to a general equation of the reaction between acids and carbonates.	PC

A visual showing a word equation with the word 'nitric acid'.	A lexical item in the teacher's verbal referring nitric acid.	S
A visual showing a word equation with the word 'sodium carbonate'.	A lexical item in the teacher's verbal referring sodium carbonate.	S
A visual showing a word equation with the word 'sodium nitrate'.	A lexical item in the teacher's verbal referring to sodium nitrate.	S
A visual showing a word equation with the word 'water'.	A lexical item in the teacher's verbal referring water.	S
A visual showing a word equation with the word 'carbon dioxide'.	A lexical item in the teacher's verbal referring carbon dioxide.	S
A visual showing a word equation with nitric acid and sodium carbonate separated by plus sign.	A lexical item in the teacher's verbal referring plus.	S
A visual showing a symbol for sodium.	A lexical item in the teacher's verbal referring sodium.	S
A visual showing a symbol for a carbonate.	A lexical item in the teacher's verbal referring to a carbonate.	S
A visual showing sodium getting two	A lexical item in the teacher's verbal saying one valency goes to magnesium and two goes to chlorine.	S
A visual showing sodium transferring one electron.	A lexical item in the teacher's verbal saying sodium transfers one electrons.	R
A visual showing sodium giving one.	A lexical item in the teacher's verbal saying sodium is giving one.	S
Visual showing nitrogen getting one.	A lexical item in the teacher's verbal saying nitrogen need one.	S

Intersemiotic Synonymy		Categories
Visual message	Verbal message	
A visual showing a plus sign.	A lexical item in the teacher's verbal referring positive	S
A visual showing a minus sign.	A lexical item in the teacher's verbal referring to negative.	S
A visual showing zero	A lexical item in the teacher's verbal referring to neutral.	S
A visual showing zero between negative and positive.	A lexical item in the teacher's verbal saying a neutral is between positive and negative.	S
A visual showing a small shaded circle orbited by electrons.	A lexical item in the teacher's verbal referring a nucleus.	R
A visual showing crosses on shells.	A lexical item in the teacher's verbal referring to electrons.	R
A visual showing a conductor wire connected from the roof to the ground.	A lexical item in the teacher's verbal referring earthing wire.	PM

A visual showing a line.	A lexical item in the teacher's verbal referring to a connecting wire.	S
A visual showing two lines, one is short, the other one is long, drawn next to each other.	A lexical item in the teacher's verbal referring to a cell.	S
A visual showing a long line in a symbol of a cell.	A lexical item in the teacher's verbal referring to positive.	S
A visual showing a short line in a symbol of a cell.	A lexical item in the teacher's verbal referring to negative.	S
A visual showing a circle with two crossed line inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a circle with a half-circle like an ohm sign inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a circuit symbol with a 'A' inside a circle.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a circuit symbol with a 'V' inside a circle.	A lexical item in the teacher's verbal referring to a voltmeter.	S
A visual showing a circuit symbol with a 'A' inside a circle.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a circuit symbol with a 'V' inside a circle.	A lexical item in the teacher's verbal referring to a voltmeter.	S
A visual showing a circuit symbol with a cross inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing an ammeter connected in series connection.	A lexical item in the teacher's verbal saying an ammeter is connected in line with a component.	R
A visual showing a voltmeter connected in parallel connection.	A lexical item in the teacher's verbal saying a voltmeter is connected across the component.	R
A visual showing a rectangular circuit symbol with a line in between.	A lexical item in the teacher's verbal referring to a fuse.	S
A visual showing a rectangular circuit symbol without a line in between.	A lexical item in the teacher's verbal referring to a resistor.	S
A visual showing a circuit symbol looking like a zig-zag line.	A lexical item in the teacher's verbal referring to a resistor.	S
A visual showing a circuit symbol like a resistor, having a crossing arrow.	A lexical item in the teacher's verbal referring to a variable resistor.	S
A visual showing the ohms sign attached to the circle.	A lexical item in the teacher's verbal referring to the ohmmeter.	S
A visual showing the ohms sign in a circle (not attached to the circle).	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing the ohms sign attached to the circle.	A lexical item in the teacher's verbal saying the filament is connected to the circle	S
A visual showing the ohms sign not attached to the circle.	A lexical item in the teacher's verbal saying the ohms sign is not connected to the circle	S

A visual showing a circuit with components connected in one line.	A lexical item in the teacher's verbal referring to a series circuit.	R
A visual showing a circuit symbol, a circle with a cross in inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a circuit symbol, a circle with cross a 'A' inside.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a circuit symbol, two dots connected with a line	A lexical item in the teacher's verbal referring to a switch.	S
A visual showing a circuit with components connected across to each other.	A lexical item in the teacher's verbal referring to a parallel circuit.	R
A visual showing a circuit symbol, two lines, one is short and the other is long.	A lexical item in the teacher's verbal referring to a cell.	S
A visual showing a circuit symbol, a circle with cross in inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a circuit symbol, two dots connected with a line	A lexical item in the teacher's verbal referring to a closed switch.	S
A visual showing a parallel circuit.	A lexical item in the teacher's verbal referring branches.	S
A visual showing an ammeter connected in line with a bulb.	A lexical item in the teacher's verbal saying an ammeter is connected in line with other components	R
A visual showing ammeter connected in series connection.	A lexical item in the teacher's verbal saying is connected in line with other components	R
A visual showing a circuit symbol, a circle with cross in inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a circuit symbol, a circle with 'A' inside.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a circuit symbol, a circle with 'V' inside.	A lexical item in the teacher's verbal referring to a voltmeter.	S
A visual showing a circuit with one line.	A lexical item in the teacher's verbal referring to a series circuit.	R
A visual showing a circuit symbol, a circle with a letter 'A' written inside.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a circuit symbol, a circle with a cross inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing components connected in one line.	A lexical item in the teacher's verbal referring to series connection.	R
A visual showing a circuit symbol, a circle with cross in inside.	A lexical item in the teacher's verbal referring to a bulb.	S
A visual showing a circuit symbol, a circle with cross a 'A' inside.	A lexical item in the teacher's verbal referring to an ammeter.	S
A visual showing a circuit symbol, two dots connected with a line	A lexical item in the teacher's verbal referring to a switch.	S
A visual showing an increase in the number of cells.	A lexical item in the teacher's verbal referring to the increase of current.	R

A visual showing an increase in the number of cells.	A lexical item in the teacher's verbal referring to the increase of voltage.	R
A visual showing a plus sign between acid and metal.	A lexical item in the teacher's verbal referring to reaction.	S
A visual showing acid and metal written before the arrow.	A lexical item in the teacher's verbal referring to reactants.	S
A visual showing salt and water written after the arrow.	A lexical item in the teacher's verbal referring to products.	S
A visual showing a word equation with hydrochloric acid and magnesium separated by plus sign.	A lexical item in the teacher's verbal referring to the reaction between hydrochloric acid and magnesium.	PC
A visual showing a word equation, a reaction between hydrochloric acid and magnesium to give magnesium chloride and hydrogen gas.	A lexical item in the teacher's verbal saying acids reacts with metals to give a metal salt and hydrogen gas.	PC
A visual showing a magnesium symbol having a two and a positive sign at the top right side.	A lexical item in the teacher's verbal saying magnesium is transferring two electrons.	R
A visual showing a chlorine symbol having a negative sign at the top right side.	A lexical item in the teacher's verbal saying chlorine need one electron.	R
A visual showing a word equation with sulfuric acid and lithium separated by plus sign.	A lexical item in the teacher's verbal referring to the reaction between sulfuric acid and lithium.	PC
A visual showing a plus sign between acid and carbonate.	A lexical item in the teacher's verbal referring to reaction.	S
A visual showing nitric acid chemical formula.	A lexical item in the teacher's verbal referring to nitric acid.	S
A visual showing sodium carbonate chemical formula.	A lexical item in the teacher's verbal referring to sodium carbonate.	S
A visual showing sodium nitrate chemical formula.	A lexical item in the teacher's verbal referring to sodium nitrate.	S
A visual showing water chemical formula.	A lexical item in the teacher's verbal referring to water.	S
A visual showing carbon dioxide chemical formula.	A lexical item in the teacher's verbal referring to carbon dioxide.	S
A visual showing a sodium carbonate symbol in brackets.	A lexical item in the teacher's verbal saying a polyatomic ion is normally put in brackets.	S
A visual showing an electric symbol of a bulb.	A lexical item in the teacher's verbal refers the symbol to a bulb.	S
A visual showing an electric symbol of a conducting wire.	A lexical item in the teacher's verbal refers the symbol to a conducting wire.	S

Intersemiotic Antonymy		Categories
Visual message	Verbal message	

A visual showing a closed circuit.	A lexical item in the teacher's verbal referring to an opening circuit.	S
A visual showing a circuit with arrows pointing from positive to negative.	A lexical item in the teacher's verbal saying charges move from negative to positive.	R
A visual showing a parallel circuit.	A lexical item in the teacher's verbal referring to components in line.	R
A visual showing a parallel circuit.	A lexical item in the teacher's verbal referring to a series circuit.	R
A visual showing an ammeter connected in line with the bulb.	A lexical item in the teacher's verbal referring to a voltmeter connected in line with the bulb.	R
A visual showing ammeter 2 without any readings.	A lexical item in the teacher's verbal saying ammeter two is 2.5 amperes.	S
A visual showing a symbol for magnesium in a magnesium chloride written without a one.	A lexical item in the teacher's verbal referring to a one at magnesium.	S

Intersemiotic Hyponymy		Category
Visual message	Verbal message	
A visual showing a sketch drawing of a house – general class.	A lexical item in the teacher's verbal referring to a modern house – sub-class	PM
A visual showing a symbol of a connecting wire – sub-class.	A lexical item in the teacher's verbal referring to the circuit symbols – general class	S
A visual showing a symbol of a cell – sub-class.	A lexical item in the teacher's verbal referring to the circuit symbols – general class	S
A visual showing an open switch – sub-class.	A lexical item in the teacher's verbal referring to switches– general class	S
A visual showing a closed switch – sub-class.	A lexical item in the teacher's verbal referring to switches– general class	S
A visual showing a symbol of a bulb draw with crossed lines inside – sub-class.	A lexical item in the teacher's verbal referring to a bulb – general class.	S
A visual showing a symbol of a bulb draw with a half-circle like an ohm sign inside – sub-class.	A lexical item in the teacher's verbal referring to a bulb – general class.	S
A visual showing a symbol of a bulb – sub-class.	A lexical item in the teacher's verbal referring electrical component – general class.	S
A visual showing two types of connections – general class.	A lexical item in the teacher's verbal referring connection across the component – sub-class.	R

A visual showing two types of connections – general class.	A lexical item in the teacher's verbal referring connection in line with the component – sub-class.	R
A visual showing a symbol of resistor that looks like a fuse, but it does not have a line in between – sub-class.	A lexical item in the teacher's verbal referring a resistor – general class.	S
A visual showing a symbol of resistor that looks like a zig zag line– sub-class.	A lexical item in the teacher's verbal referring a resistor – general class.	S
A visual showing a symbol of a variable resistor that looks like a fuse, but it does not have a line in between, and it has a crossing arrow – sub-class.	A lexical item in the teacher's verbal referring a variable resistor – general class.	S
A visual showing a symbol of a variable resistor that looks like a zig-zag line, and it has a crossing arrow – sub-class.	A lexical item in the teacher's verbal referring a variable resistor – general class.	S
A visual showing a symbol of a bulb drawn with an ohm sign inside a circle – sub-class.	A lexical item in the teacher's verbal referring to a bulb – general-class.	S
A visual showing a series circuit – sub-class.	A lexical item in the teacher's verbal there are two types of circuits – general class	R
A visual showing a closed switch – sub-class.	A lexical item in the teacher's verbal referring to a switch – general class	S
A visual showing a positive sign – sub-class.	A lexical item in the teacher's verbal referring to charges – general class	S
A visual showing a negative sign – sub-class.	A lexical item in the teacher's verbal referring to charges – general class	S
A visual showing a parallel circuit – sub-class.	A lexical item in the teacher's verbal there are two types of circuits – general class	R
A visual showing a closed switch – sub-class.	A lexical item in the teacher's verbal referring to a switch – general class	S
A visual showing a symbol of a bulb – sub-class	A lexical item in the teacher's verbal referring to electric components – general class	S
A visual showing a series circuit – sub-class.	A lexical item in the teacher's verbal referring to a circuit – general class	R
A visual showing a general equation for acid and metal – sub-class.	A lexical item in the teacher's verbal referring to a general equation – general class.	PC
A visual showing a word equation for the reactions between hydrochloric acid and magnesium – sub-class.	A lexical item in the teacher's verbal referring to equations between acids and metals– general class.	PC
A visual showing a symbol for magnesium – sub-class.	A lexical item in the teacher's verbal referring to group two metals – general class.	S

A visual showing a symbol for chlorine – sub-class.	A lexical item in the teacher's verbal referring to group seven elements – general class.	S
A visual showing a general equation for acid and carbonate – sub-class.	A lexical item in the teacher's verbal referring to a general equation – general class.	PC
A visual showing carbon dioxide in a general equation – sub-class.	A lexical item in the teacher's verbal referring to gas – general class.	S
A visual showing a word equation with sodium nitrite – sub class.	A lexical item in the teacher's verbal referring to salts – general class.	PC
A visual showing a word equation with sodium carbonate – sub class.	A lexical item in the teacher's verbal referring to carbonates – general class.	S
A visual showing a word equation of sodium carbonate – sub class.	A lexical item in the teacher's verbal referring to metal carbonates – general class.	S
A visual showing a symbol for sodium – sub-class.	A lexical item in the teacher's verbal referring to group one element – general class.	S
A visual showing a symbol for a carbonate – sub-class.	A lexical item in the teacher's verbal referring to a polyatomic ion – general class.	S
A visual showing a symbol for a nitrate – sub-class.	A lexical item in the teacher's verbal referring to polyatomic ion – general class.	S
A visual showing a diagram of an electric circuit – general-class.	A lexical item in the teacher's verbal referring to non-conductors – sub-class.	R
A visual showing an electric symbol of a contacting wire – sub-class.	A lexical item in the teacher's verbal referring to conductors and non-conductors – general-class.	S

Intersemiotic Meronymy		Category
Visual message	Verbal message	
A visual showing a number line – whole.	A lexical item in the teacher's verbal referring to negative – part of the whole.	S
A visual showing a number line – whole.	A lexical item in the teacher's verbal referring to positive – part of the whole.	S
A visual showing a number line – whole.	A lexical item in the teacher's verbal referring to neutral – part of the whole.	S
A visual showing an atomic structure – whole.	A lexical item in the teacher's verbal referring to nucleus – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher's verbal referring to protons – part of the whole.	R

A visual showing an atomic structure – whole.	A lexical item in the teacher’s verbal referring to shells – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher’s verbal referring to electrons – part of the whole.	R
A visual showing a nucleus – whole.	A lexical item in the teacher’s verbal referring to protons – part of the whole.	R
A visual showing a shell – whole.	A lexical item in the teacher’s verbal referring to electrons – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher’s verbal referring to protons – part of the whole.	R
A visual showing an atomic structure – whole.	A lexical item in the teacher’s verbal referring to electrons – part of the whole.	R
A visual showing a nucleus – whole.	A lexical item in the teacher’s verbal referring to protons – part of the whole.	R
A visual showing a shell – whole.	A lexical item in the teacher’s verbal referring to electrons – part of the whole.	R
A visual showing a number line – whole.	A lexical item in the teacher’s verbal referring to negative – part of the whole.	S
A visual showing a number line – whole.	A lexical item in the teacher’s verbal referring to positive – part of the whole.	S
A visual showing a number line – whole.	A lexical item in the teacher’s verbal referring to neutral – part of the whole.	S
A visual showing an earthing system – whole.	A lexical item in the teacher’s verbal referring earthing wire – part of the whole.	PM
A visual showing an earthing system – whole.	A lexical item in the teacher’s verbal referring a metal spike – part of the whole.	PM
A visual showing a house – whole.	A lexical item in the teacher’s verbal referring earthing wire – part of the whole.	PM
A visual showing a house – whole.	A lexical item in the teacher’s verbal referring a metal spike – part of the whole.	PM
A visual showing a house – whole.	A lexical item in the teacher’s verbal referring the roof – part of the whole.	PM
A visual showing a symbol of a connecting wire – part of the whole.	A lexical item in the teacher’s verbal referring a circuit – whole.	S

A visual showing a symbol of a cell – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a cell – whole.	A lexical item in the teacher's verbal referring positive – part of the whole.	S
A visual showing a symbol of a cell – whole.	A lexical item in the teacher's verbal referring negative – part of the whole.	S
A visual showing a symbol of an open switch – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a closed switch – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol a bulb – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a voltmeter – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of an ammeter – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a voltmeter – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of an ammeter – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a bulb – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a fuse – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a resistor – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a variable resistor – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of an ohmmeter – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a bulb – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of ohmmeter – whole.	A lexical item in the teacher's verbal referring to a filament.	S
A visual showing a symbol of a connecting wire – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of cells – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of bulbs – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a switch – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of an ammeter – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring a bulb – part of the whole.	R

A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring an ammeter – part of the whole.	R
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring a switch – part of the whole.	R
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring a current – part of the whole.	R
A visual showing cells – whole.	A lexical item in the teacher's verbal referring positive terminal – part of the whole.	S
A visual showing cells – whole.	A lexical item in the teacher's verbal referring negative terminal – part of the whole.	S
A visual showing a symbol of a connecting wire – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of cells – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of bulbs – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a switch – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring a bulb – part of the whole.	R
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring an ammeter – part of the whole.	R
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring a switch – part of the whole.	R
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring a cell – part of the whole.	R
A visual showing a circuit – whole.	A lexical item in the teacher's verbal referring an ammeter – part of the whole.	R
A visual showing a symbol of a connecting wire – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of cells – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of bulbs – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a switch – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S
A visual showing a symbol of a connecting wire and bulb – part of the whole.	A lexical item in the teacher's verbal referring a complete circuit – whole.	S
A visual showing a symbol of a connecting wire – part of the whole.	A lexical item in the teacher's verbal referring a circuit – whole.	S

A visual showing a symbol of a bulb – part of the whole.	A lexical item in the teacher’s verbal referring to a circuit – whole.	S
A visual showing a symbol of an ammeter – part of the whole.	A lexical item in the teacher’s verbal referring to circuit – whole.	S
A visual showing a symbol of a connecting – part of the whole.	A lexical item in the teacher’s verbal referring a circuit – whole.	S
A visual showing a symbol of cells – part of the whole.	A lexical item in the teacher’s verbal referring a circuit – whole.	S
A visual showing a symbol of bulbs – part of the whole.	A lexical item in the teacher’s verbal referring a circuit – whole.	S
A visual showing a symbol of a switch – part of the whole.	A lexical item in the teacher’s verbal referring a circuit – whole.	S
A visual showing a symbol of an ammeter – part of the whole.	A lexical item in the teacher’s verbal referring a circuit – whole.	S
A visual showing a symbol of cells – whole.	A lexical item in the teacher’s verbal referring voltage – part of the whole.	S
A visual showing a general equation for the reactions between acids and metals – whole.	A lexical item in the teacher’s verbal referring acid – part of the whole.	PC
A visual showing a general equation for the reactions between acids and metals – whole.	A lexical item in the teacher’s verbal referring metals – part of the whole.	PC
A visual showing a general equation for the reactions between acids and metals – whole.	A lexical item in the teacher’s verbal referring salt – part of the whole.	PC
A visual showing a general equation for the reactions between acids and metals – whole.	A lexical item in the teacher’s verbal referring hydrogen gas – part of the whole.	PC
A visual showing a word equation for the reactions between hydrochloric acid and magnesium – whole.	A lexical item in the teacher’s verbal referring to hydrochloric acid – part of the whole.	PC
A visual showing a word equation for the reactions between hydrochloric acid and magnesium – whole.	A lexical item in the teacher’s verbal referring to magnesium – part of the whole.	PC
A visual showing a word equation for the reactions between hydrochloric acid and magnesium – whole.	A lexical item in the teacher’s verbal referring to magnesium chloride – part of the whole.	PC
A visual showing a word equation for the reactions between hydrochloric acid and magnesium – whole.	A lexical item in the teacher’s verbal referring hydrogen gas – part of the whole.	PC
A visual showing a symbol for magnesium – part of the whole.	A lexical item in the teacher’s verbal referring to a crossing of valencies between magnesium and chlorine – whole.	S
A visual showing a symbol for chlorine – part of the whole.	A lexical item in the teacher’s verbal referring to a crossing of valencies between magnesium and chlorine – whole.	S

A visual showing two and a positive sign – part of the whole.	A lexical item in the teacher's verbal referring to a crossing of valencies between magnesium and chlorine – whole.	S
A visual showing a negative sign – part of the whole.	A lexical item in the teacher's verbal referring to a crossing of valencies between magnesium and chlorine – whole.	S
A visual showing two lines crossing each other – part of the whole.	A lexical item in the teacher's verbal referring to a crossing of valencies between magnesium and chlorine – whole.	R
A visual showing a word equation for the reactions between sulfuric acid and lithium – whole.	A lexical item in the teacher's verbal referring to sulfuric acid – part of the whole.	PC
A visual showing a word equation for the reactions between sulfuric acid and lithium – whole.	A lexical item in the teacher's verbal referring to lithium – part of the whole.	PC
A visual showing a word equation for the reactions between sulfuric acid and lithium – whole.	A lexical item in the teacher's verbal referring to lithium sulfate – part of the whole.	PC
A visual showing a word equation for the reactions between sulfuric acid and lithium – whole.	A lexical item in the teacher's verbal referring hydrogen gas – part of the whole.	PC
A visual showing a general equation for the reactions between acids and carbonate – whole.	A lexical item in the teacher's verbal referring acid – part of the whole.	PC
A visual showing a general equation for the reactions between acids and carbonate – whole.	A lexical item in the teacher's verbal referring carbonate – part of the whole.	PC
A visual showing a general equation for the reactions between acids and carbonate – whole.	A lexical item in the teacher's verbal referring salt – part of the whole.	PC
A visual showing a general equation for the reactions between acids and carbonate – whole.	A lexical item in the teacher's verbal referring water – part of the whole.	PC
A visual showing a general equation for the reactions between acids and carbonate – whole.	A lexical item in the teacher's verbal referring carbon dioxide – part of the whole.	PC
A visual showing a word equation for the reactions between nitric acid and sodium carbonate – whole.	A lexical item in the teacher's verbal referring to nitric acid – part of the whole.	PC
A visual showing a word equation for the reactions between nitric acid and sodium carbonate – whole.	A lexical item in the teacher's verbal referring to sodium carbonate – part of the whole.	PC
A visual showing a word equation for the reactions between nitric acid and sodium carbonate – whole.	A lexical item in the teacher's verbal referring to sodium nitrate – part of the whole.	PC

A visual showing a word equation for the reactions between nitric acid and sodium carbonate – whole.	A lexical item in the teacher's verbal referring to water – part of the whole.	PC
A visual showing a word equation for the reactions between nitric acid and sodium carbonate – whole.	A lexical item in the teacher's verbal referring to carbon dioxide – part of the whole.	PC
A visual showing crossing of valencies between sodium and carbonate – whole.	A lexical item in the teacher's verbal referring sodium – part of the whole.	R
A visual showing crossing of valencies between sodium and carbonate – whole.	A lexical item in the teacher's verbal referring carbonate – part of the whole.	R
A visual showing crossing of valencies between sodium and nitrate – whole.	A lexical item in the teacher's verbal referring sodium – part of the whole.	R
A visual showing crossing of valencies between sodium and nitrate – whole.	A lexical item in the teacher's verbal referring nitrate – part of the whole.	R

Appendix K: Lesson observations analytical memo for Helena

PM – Physical material **PC** – Processes **S** – Symbolism **R** – Resemblance

Intersemiotic Repetition		Categories
Visual message	Verbal message	
A visual showing a periodic table having metals and non-metals elements.	A lexical item in the teacher's referring to metals and none metals in the periodic table.	R
A visual showing a periodic table having metals on the left-hand side.	A lexical item in the teacher's saying metals are found on the left-hand side of the periodic table.	R
A visual showing a periodic table having non-metals on the right-hand side.	A lexical item in the teacher's saying non-metals are found on the right-hand side of the periodic table.	R
A visual showing a periodic table with oxygen on the right side of the periodic table.	A lexical item in the teacher's saying oxygen is on right side of the periodic table	R
A visual showing an arrow representing a reaction series.	A lexical item in the teacher's verbal saying the reactivity series is indicated with an arrow.	S
A visual showing metals arrange in a reactivity series.	A lexical item in the teacher's verbal saying a reactivity is the arrangement of metals.	R
A visual showing an arrow pointing up.	A lexical item in the teacher's verbal saying the arrow of a reaction points upward.	S
A visual showing the less reactivity metals at the bottom the arrow.	A lexical item in the teacher's verbal saying less reactivity metals are at the bottom.	R
A visual showing the most reactivity metals at the top of the arrow.	A lexical item in the teacher's verbal saying most reactivity metals are at the top of the arrow.	R
A visual showing gold among the transition metals in the periodic table.	A lexical item in the teacher's verbal saying gold is a transition metal.	S
A visual showing copper among the transition metals in the periodic table.	A lexical item in the teacher's verbal saying copper is a transition metal.	S
A visual showing a chemical symbol of copper at Tsumeb in the map.	A lexical item in the teacher's verbal saying copper is mined in Tsumeb.	S
A visual showing a chemical symbol of lead at Rosh Pinah and Compat in the map.	A lexical item in the teacher's verbal saying lead is mined in Rosh Pinah and Combat.	S
A visual showing a chemical symbol of silver at Tsumeb in the map.	A lexical item in the teacher's verbal saying silver is mined in Tsumeb.	S
A visual showing a chemical symbol of diamond at Oranjemund in the map.	A lexical item in the teacher's verbal saying diamond is mined in Oranjemund.	S
A visual showing a pot.	A lexical item in the teacher's verbal referring to a pot.	PM

A visual showing a condenser connected to the pot.	A lexical item in the teacher's verbal saying the condenser is connected to the pot.	PM
A visual showing a condenser.	A lexical item in the teacher's verbal referring to condensation.	PH and PC
A visual showing a bottle drawn down the pipe.	A lexical item in the teacher's verbal saying the liquid will be collected in the bottle.	PM

Intersemiotic Synonymy		Categories
Visual message	Verbal message	
A visual showing an electric symbol of a bulb.	A lexical item in the teacher's verbal refers the symbol to a bulb.	S
A visual showing an electric symbol of a conducting wire.	A lexical item in the teacher's verbal refers the symbol to a conducting wire.	S
A visual showing a periodic table with oxygen, nitrogen and carbon on the right-hand side.	A lexical item in the teacher's verbal saying oxygen, nitrogen and carbon are non-metal.	R
A visual showing a periodic table with sodium, magnesium, copper, iron and lithium on the left-hand side.	A lexical item in the teacher's verbal saying sodium, magnesium, copper, iron and lithium are metal.	R
A visual showing copper in the middle of the periodic table.	A lexical item in the teacher's verbal saying copper is a transition metal.	R
A visual showing copper written down the reactivity series.	A lexical item in the teacher's verbal saying copper is less reactivity.	S
A visual showing gold and silver far down the reactivity series.	A lexical item in the teacher's verbal saying gold and silver are unreactive.	S
A visual showing a map of main ores deposits in Namibia.	A lexical item in the teacher's verbal referring to the minerals mined in Namibia	R
A visual showing a chemical symbol of gold at Rubicon (a mine in Karibib)	A lexical item in the teacher's verbal saying gold is mined in Karibib.	S
A visual showing a chemical symbol of tin at Navachab (a mine in Uis)	A lexical item in the teacher's verbal saying tin is mined in Uis.	S
A visual showing a picture of the preparation of Oshiwambo traditional gin (<i>ombike</i>).	A lexical item in the teacher's verbal referring the picture to something used to make Ovambo liquor.	PC
A visual showing smoke.	A lexical item in the teacher's verbal referring to fire.	PC
A visual showing flames.	A lexical item in the teacher's verbal referring to heat.	PC

Intersemiotic Antonymy		Categories
Visual message	Verbal message	

A visual showing a periodic table without a zig-zag line separating metals and non-metals	A lexical item in the teacher's saying metals and non-metals are separated by zig-zag line.	R
A visual showing a decrease of the red colour as the arrow goes up.	A lexical item in the teacher's verbal saying the reactivity increase the arrow goes up.	R
A visual showing oxygen (non-metal) in the reactivity series.	A lexical item in the teacher's verbal referring to reactivity series for metals.	S
A visual showing names of towns on right side on the paper (key for the map)	A lexical item in the teacher's verbal saying name of the metal are on the left side of the paper	S
A visual showing a chemical symbol of zinc at Namdeb (a mine in Oranjemund) and at Tsumeb.	A lexical item in the teacher's verbal saying zinc is mine in Scorpion Zinc.	S
A visual showing diamond in the Namibian map.	A lexical item in the teacher's verbal referring to the metals mined in Namibia	S
A visual showing a condenser.	A lexical item in the teacher's verbal referring to evaporation.	PM

Intersemiotic Hyponymy		Category
Visual message	Verbal message	
A visual showing a periodic table – main-class.	A lexical item in the teacher's verbal referring to metal – sub-class.	R
A visual showing a periodic table – main-class.	A lexical item in the teacher's verbal referring to non-metal – sub-class.	R
A visual showing a periodic table – main-class.	A lexical item in the teacher's verbal referring to elements – sub-class.	R
A visual showing on a periodic table – main-class.	A lexical item in the teacher's verbal referring to oxygen, nitrogen, carbon, sodium, magnesium, copper, iron and lithium – sub-classes.	R
A visual showing calcium, sodium and potassium – sub-class.	A lexical item in the teacher's verbal referring to most reactive metals – general-class.	S
A visual showing unreactive metal – general-class.	A lexical item in the teacher's verbal referring gold and silver – sub-class.	S
A visual showing transition metal in a periodic table – general-class.	A lexical item in the teacher's verbal referring gold and copper – sub-class.	S
A visual showing silver, lead, gold, copper and zinc in the Namibia map – sub-class.	A lexical item in the teacher's verbal referring to the minerals mined in Namibia – general-class.	S
A visual showing a Namibia map – general-class.	A lexical item in the teacher's verbal referring to Karibib, Uis, Oranjemund, Tsumeb and Rosh Pinah – sub-class.	R

A visual showing a picture demonstrating the preparation of Oshiwambo traditional gin (ombike) – sub-class	A lexical item in the teacher’s verbal referring to ombike yeendunga (palm fruit gin) – general-class.	PC
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Intersemiotic Meronymy		Category
Visual message	Verbal message	
A visual showing a diagram of an electric circuit – whole.	A lexical item in the teacher’s verbal referring to a bulb – part of the whole.	R
A visual showing a diagram of an electric circuit – whole.	A lexical item in the teacher’s verbal referring to conducting wire – part of the whole.	R
A visual showing a diagram of an electric circuit – whole.	A lexical item in the teacher’s verbal referring to conductors – part of the whole.	R
A visual showing a diagram of an electric circuit – whole.	A lexical item in the teacher’s verbal referring to a switch – part of the whole.	R
A visual showing a diagram of an electric circuit – whole.	A lexical item in the teacher’s verbal referring to bulb – part of the whole.	R
A visual showing a picture demonstrating the preparation of Oshiwambo traditional gin (ombike) – whole.	A lexical item in the teacher’s verbal referring to condensation – part of the whole.	PC
A visual showing a picture demonstrating the preparation of Oshiwambo traditional gin (ombike) – whole.	A lexical item in the teacher’s verbal referring to eendunga (palm fruits) – part of the whole.	PC
A visual showing a picture demonstrating the preparation of Oshiwambo traditional gin (ombike) – whole.	A lexical item in the teacher’s verbal referring to evaporation – part of the whole.	PC
A visual showing a picture of a condenser – whole.	A lexical item in the teacher’s verbal referring to copper – part of the whole.	PM

Appendix L: Potential uses of the verbal/visual mode identified by the researcher

Ananias' lessons

Potential uses of the verbal/visual resource identified by the researcher
Lexical items in the teacher's verbal explanation referring to the process involved in the generation of electricity. I could be better to have a visual showing how water turns the turbines, which will turn the generator, which will generate electricity. A picture of the whole process would have helped the teacher to communicate the message better.
There is a symbol of a cell in both the two circuits, but there is no a lexical item in the teacher's verbal that refers to a cell.
It would be useful to have circuit diagrams with resistor having the same resistance
There is a line a drawn from the nucleus of the atom indicating that the element has 8 protons and 8 neutrons, but it is not mentioned in the teacher's verbal.
The teacher drawn different kinds of atoms, but there is no a lexical item in the teacher's verbal indicating which atom represent an element, and what are the other items would represent.

Eino's lessons

Potential uses of the verbal/visual resource identified by the researcher'
There are lexical items in the teacher's verbal explanation referring to certain physical properties of metals and non-metals. The teachers could have used pictures to show learners some of the properties – example ductileness and colours.
There a lexical item in the teacher's verbal saying current is the same ant any point in a series circuit, but there is no a visual showing ammeters with the same readings.

Helena's lessons

Potential uses of the verbal/visual resource identified by the researcher'
The teacher could have provided pictures of copper wire in electric cable when teaching about uses of metals.
There was also a potential of presenting picture of coin money when teaching about uses of metals.
A picture of mercury in a thermometer could also be provided when teaching about uses of metals.
The teacher could also have provided pictures of aluminium foils when teaching about uses of metals.
The teacher could have used pictures of metals in water to show that these metals are unreactive.
The teacher could have used picture of metals coated with silver to show that silver is less reactive.
The teacher could have provided learners with pictures some metals mined in Namibia
The teacher could have provided pictures showing an open mining.
The teacher could have provided pictures of ores and metals for learners to differentiate the two.