Exploring the lexical and semantic access afforded by novice and experienced Namibian Physical Science teachers' talk during Electricity and Magnetism lessons

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Declaration of Originality

I, the undersigned, hereby declare that the work contained in this thesis is my original work. It has not been previously submitted in any form for assessment or degree in any other higher education institution. All the ideas, quotations and other materials used in this study derived from the work of other people have been included in the list of references as per the Departmental Guidelines of Rhodes University.

31 January 2022

Signature **Date**

Dedication

I dedicate this thesis to my beloved grandmother Paulina Mbahuma-Musambani.

Acknowledgement

First and foremost, I would like to thank the almighty GOD for according me the opportunity to complete my thesis. Secondly, I would like to thank my wife and my kids for their continuous unwavering support and patience throughout the course of this journey. Thirdly, to Dr. Kavish Jawahar, I thank you very much for your superb supervisory skills and most importantly for your patience. This thesis was practically impossible without your assistance. My heartfelt appreciation goes to Dr. Karen Ellery for her willingness to co-supervise my work. Your insights and expertise on LCT have helped to shape and reshape this thesis.

Abstract

Challenges to learners' meaning-making in the topic of electricity and magnetism contributes to underperformance in grade 10 Physical Science in Namibian schools. Teacher talk in content-based classrooms not only contributes to learners' language development (Gibbons, 2003), but also facilitates meaning-making and cumulative knowledge-building (Halliday, 1999). However, it is possible that there are differences between the classrooms talk of novice and experienced Namibian Physical Science teachers. An understanding of differences between experienced and novice Namibian science teacher talk could inform teacher training and professional development and potentially help improve learners' meaning-making in topics such as electricity and magnetism. However, no study could be found in the Namibian context which explored whether novice and experienced teacher talk afforded similar semantic and lexical access to meaning-making. This research gap provided a strong rationale for undertaking the study reported in this thesis.

The study sought to investigate the extent to which novice and experienced grade 10 Namibian Physical Science teachers' classroom talk provides semantic and lexical access to learners for the topic of electricity and magnetism. The research is informed by Legitimation Code Theory (LCT) and Systemic Functional Linguistics (SFL). Research has shown that the two theories are complementary and can be used to characterize teachers' pedagogical practices (Maton, 2014). A quantitative case study methodology was followed in this study with LCT's semantic density and SFL's lexical density as analytical tools to analyze the two teachers' classroom talk.

The results from a t-test for semantic density show that there is a significant difference in the means for "semantic density waving" criterion (t-value of -2.331; p-value for 2 tail test at 95% level of 0.0040) and for the "linking downward escalators or single references" criterion (t-value of 4.649; p-value for 2 tail test at 95% level of 0.001) of teacher talk by the teachers. The overall results for semantic density indicate that the experienced teacher affords better epistemological access through semantic waves than the novice teacher, whereas the novice teacher affords better epistemological access through semantic range and semantic flow. In terms of lexical density, both teachers afforded similar access, characterized by their talk veering towards the level of information density associated with written text.

The study makes a methodological contribution to science education research through its characterization of novice and experienced teachers’ talk in terms of semantic waves and lexical density. This study also provides empirical insight into the differences between language use by novice and experienced Namibian Physical Science teachers, which can inform the work of educational institutions, advisory and inspectorate services in the ministry of education, and school managers. Relevant Namibian stakeholders are encouraged to consider including the topics of semantic density and lexical density, in continuous professional development programmes towards improving the meaning-making affordances of science teachers’ talk.

Keywords:
Science teacher talk, epistemological access, Legitimation code theory, Systemic functional linguistic, semantic density, lexical density, electricity and magnetism

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LIST OF ABBREVIATIONS AND ACRONYMS

SFL- Systemic Functional Linguistics

LCT- Legitimation Code Theory

LD- Lexical Density

SD- Semantic Density

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CHAPTER 1: INTRODUCTION

Wellington and Osborne (2001) state that in order to improve the quality of science education, teachers must give considerable attention to the use of language. Lemke (1990) also asserts that teacher's language use during science discourse may hamper or improve acquisition of scientific literacy by learners. However, literature suggest that use of language is not the same for novice and experienced teachers (Karataş & Karaman, 2013). The objective of this study was to explore teacher talk by one experienced and one novice Physical Science teacher during grade 10 lessons on electricity and magnetism. The focus was on the lexical and semantic access afforded by the teachers' talk.

The knowledge gap that becomes evident from this chapter is that no study has been done in Namibia which addresses lexical and semantic access provided by experienced and novice teachers for the difficult topic of electricity and magnetism. In this chapter the context of the study is explained, which includes a discussion of the importance of science graduates for a country, and the global and national challenges which are experienced by learners who study Physical Sciences both at tertiary and secondary school levels. The chapter also outlines the significance of the current study, introduces the research questions and finally concludes with an outline of the thesis chapters.

1.1. Importance of science graduates to a country

We are living in a society characterized by a strong reliance on science (Cox, 2016). For example, major developmental decisions taken by countries are informed by science (Ibid). Cox (2016) argues that economies are in fact, driven by advances in STEM (science, technology, engineering and mathematics). A functional society requires citizens to understand science as a thinking framework for advancement (Cox, 2016). Having more science graduates is advantageous for a country - college graduates with expertise in science help the country to be economically strong, create jobs, and thriving new industries driven by new technologies (Gerardi, 2012). The corollary is also true - a society in which large numbers of people are unfamiliar or uncomfortable with scientific developments faces a great economic disadvantage in globalized competition (Gerardi, 2012). Chetty (2012) is in agreement regarding science and scientists playing an important role in determining choices and implementing development strategies for a country.

Namibia has adopted Vision 2030 (Government of the Republic of Namibia, 2004) - a policy document that outlines long term development goals for Namibia. It is envisaged that by the year 2030, Namibia will improve the quality of life of its people to the level of those of their counterparts in the developed world (Government of the Republic of Namibia, 2004). Amongst other factors, education, science and technology are considered the main driving forces to achieve Vision 2030 (ibid, 2014). Namibia needs a strong workforce that is trained in science (Government of the Republic of Namibia, 2004) and that may be achieved if Namibia produces competent science graduates. Chetty (2012) says that the impetus for transition of a country from developing to developed has to come from scientists and other sectors of society. In a world where globalization and competitiveness are eminent, some developing countries may fair considerably better than others because of their strong work force that is trained in science (Gerardi, 2012).

Many countries have reported declining proportions of students who enter the science fields (Venville, Rennie, Hanbury & Longnecker, 2013). This trend is mostly observed in developing countries (Lewin, 1993), of which Namibia is one example. It is worrisome because inadequate numbers of scientists may have detrimental consequences for the country in terms of economic development (Venville et al., 2013). It is therefore imperative for the schooling system in Namibia to prepare learners well in order for them to possibly continue studying science courses at tertiary level. Better performance of learners in science at school level may increase enrollment in science at tertiary level and eventually could add more science graduates to the human capital of Namibian.

Science graduates may be important for Namibia to achieve vision 2030 and its developmental goals as alluded by Venville et al. (2013). One of the developmental goals raised in vision 2030 is to reduce poverty by creating wealth. Jaffe (2013) in his study of relevance of science in development concluded that scientific productivity of countries correlates well with present and future wealth. It is on that score that science graduates could help alleviate poverty in Namibia. Jaffe (2013) further says that science favors societal development by means of providing governments with rational atmosphere for implementation of sound policies related to such things as the economy, health, agriculture and education. Namibia may benefit in the sense that the science graduates may get involved in policy formulation in order to improve the health, agriculture, education and other sectors so that societal needs are met.

1.2. Tertiary science education: international and Namibian challenges

Internationally, concerns have been raised about the low enrollment figures of Physics students at universities (National Institute of Physics, 2011). It has long been observed that there is a high attrition rate for science and technology related courses in universities (American Association of Physics Teachers [AART], 1996). Despite international and national efforts to alleviate the shortage of science professionals, the high attrition rate in science, endures (Linder, 2013). Fensham (2008) indicates that for both successful and unsuccessful students, science remains more difficult than a number of other subjects. Research on different Physical Science topics and concepts have shown that there are many which pose challenges to students (Fensham, 2008).

Namibia has experienced a shortage of science teachers (Kisting, 2011) and professionals in other scientific careers (Tjikuua, 2006), and as a result a cabinet directive instructed respective Ministries to recruit science teachers and science related professionals from other SADC countries. The shortage of science professionals causes a downward spiral. Lipsett (2004) explains that lack of qualified science professionals puts the country and its people at a higher risk of: lack of scientific knowledge, inability to apply science knowledge correctly, and a lack of research output related to science. This can be detrimental to the country because sectors such as education, agriculture and technology may be affected negatively (Musyoka, 2000; Mutua, 2007).

With reference to the education sector, it can have a damaging effect on quality of teacher's science content knowledge that could have been gained from tertiary institutions (Lipsett, 2004). Poor science content knowledge of a teacher may cause learners to fail. According to Lipsett (2004) fewer secondary school learners will enter universities or will take up science courses at universities. Students in higher education institutions in Namibia face many challenges in the mathematics and Science fields (Namibian National Commission on Research, Science & Technology [NCRST], 2014, p.1). The same document highlights that schools do not adequately prepare learners to face these challenges at the university level (NCRST, 2014) resulting in few learners enrolling in science courses at universities.

1.3. School Physical Sciences education: global challenges

The teaching and learning of high school Physical Sciences has been researched for a number of years. Physical Sciences, deals with the study of the physical world and it is composed of two major branches: chemistry and physics (Wilson, 2018). Chemistry is the study of the properties and structure of matter while physics is the study of relationship between matter and energy (Wilson, 2018). High school Physical Sciences lay a foundation for entrance to scientific courses at university and hence into scientific careers (Linder, 2013). This warrants inclusion of education at the lower levels in consideration of factors contributing to decreasing numbers of university science graduates.

Studies have also shown that teachers have challenges delivering the content successfully (Wellington & Ireson, 2018). According to Bahar and Polat (2007) researchers and innovators employ different practices to improve learning and teaching of Physical Sciences. Despite these constructive attempts to ease the learning and teaching difficulties in the subject, the challenges still persist in classrooms (Bahar & Polat, 2007). Studies have indicated that learners being challenged by Physical Science hinders their acquisition of scientific literacy (Wellington & Ireson, 2018). This is echoed by Laugksch and Spargo (1999) who reveal that Physical Science plays a major role in improving science literacy. Holbrook and Rannikmae (2009) argue that teaching for scientific literacy encompasses the issues related to acquisition of science content, an appreciation of the nature of science, the improvement of personal attributes and the acquisition of socio-scientific skills and values. With this study I concentrate on the science subject competencies within the Physical Science.

According to Kelly (2011) scientific literacy is influenced through language used during discussions within and between societal groups. These societal groups may be exemplified by the science discourse community, which includes the learners and the teacher. Kelly (2011) further asserts that because the use of language is central to the creation and communication of knowledge, any science classrooms with a productive epistemic environment will include an emphasis on language use and dialogic interaction as part of scientific discourse. The discourse of Physical Science is distinct - compared to other science subjects, it contains more abstract and challenging concepts (Nutta, Bautista & Butler, 2011).

Herbert (2008) also reminds us that Physical Science words are dense and contextually difficult for learners to understand. Some studies reveal that teachers' instruction may not be contextualized and thus not relate to learners' experiences and prior knowledge (Cox-Peterson, Melber & Patchen, 2012), contributing to learners' failure (Powell, 2014). Lemke (1990) and Gibbons (2003) recommend that teachers talk during scientific discourse should initially contain more informal everyday terms as opposed to having many technical science terms from the onset. By doing so they may be able to sustain semantic relationships among scientific terms and make science more accessible to learners. It is therefore pertinent that Physical Science teachers be mindful of their use of language, as it may hamper learners' acquisition of scientific literacy.

1.4. The subject of Physical Science in Namibia

Physical Science is one of the components of school science (Wellington & Ireson, 2018), and covers the disciplines of Physics and Chemistry (Powell, 2014). Physical Science in the Namibian context, forms part of the Natural Science. It is offered as a school subject from grade 8-12, being compulsory in Grade 8-10 and optional from grade 11 (MoE, 2010). This study focuses on the topic of electricity and magnetism which is an aspect of Physics, within the Namibian school subject of Physical Science. As listed in the grade 10 syllabus the following sub-topics are studied under the topic of electricity and magnetism: current, voltage, resistance, ohm's law, electrical power, magnetism, electricity at home, and magnetic effects on electric current (MoE, 2010).

One of the assessment objectives in the syllabus requires learners to be able to demonstrate scientific literacy in their examination and tests. It is clearly stipulated that learners should be able to demonstrate knowledge and understanding of: "scientific language, terminology, the use of scientific facts, concepts, patterns and principles in order to solve problems and explain natural phenomena" (MoE, 2010, p. 63). The average annual Grade 10 Physical Science examination mark in Namibia was below fifty percent in consecutive recent years (MoE, 2012; MoE, 2013; MoE 2014; MoEAC, 2015; MoEAC, 2016). This is problematic because consequences such as fewer learners being eligible for science-related courses at tertiary level, will have a negative impact on mobilization of human resources in Namibia. Dr. Hage Geingob, the current President of Namibia recently reminded students at the graduation ceremony of the Namibia University of Science and Technology that for Namibia to become an industrialized nation by the year 2030, they ought to embrace and study science (Brandt, 2017). That may be more likely if the challenges that are experienced at secondary school level regarding acquisition of scientific literacy, are addressed.

Examiners' reports for Namibian Junior Secondary Certificate (JSC) Physical Science, mention that grade 10 Physical Science learners experience challenges to meaning- making in the topic of electricity and magnetism, thus contributing to poor performance (MoE, 2012; MoE, 2013; MoE 2014; MoEAC, 2015; MoEAC, 2016). This underscores the need to explore access to meaning-making in the Namibian Physical Science classroom.

1.5. Meaning-making and science learning in Namibia

The Southern Africa Consortium for Monitoring Educational Quality (SACMEQ) has undertaken educational studies which include Namibia. SACMEQ is an international non-profit organization that consists of sixteen Ministries of Education from Eastern and Southern Africa. They share experiences and expertise between countries in terms of monitoring and evaluating the conditions of schooling and the quality of education. The main focus of SACMEQ's work has been to implement research and training programs to equip educational planners and researchers with relevant technical skills, such as research design, instrument construction, sampling, data analysis and report writing (Amadhila et al., 2011).

SACMEQ pointed to low level of English reading skills among Namibian grade 6 learners (Amadhila et al., 2011). The SACMEQ tests and surveys have focused on aspect of reading literacy and mathematics performance in Namibia and other Southern African countries. The reading literacy test has focused on items such as learners' basic reading skills (learners' abilities to interpret meaning), reading for meaning, and interpretive reading (contextualization of meaning). The items are directly linked to the focus of this study which is meaning-making. For example, the scores for interpreting meanings, reading for meanings, and contextualization of meanings in the SACMEQ II results were 26.6 %, 14.3% and 6.0 %, respectively. Low levels in meaning-making were observed in SACMEQ III as well (basic reading - 10.8%, reading for meanings - 25.1 %, interpretive reading - 25.5%). Both SAMEQ II & III results indicate that leaners generally experience problems with meaning-making.

It is useful that SACMEQ studies are focused on English. Scott (2008) points out that language plays an important role in science teaching and teaching. The author further acknowledged that language goes hand in hand with the development of scientific ideas. Lemke (1990) confirmed that language and science are interdependent. Merging language and science in classrooms may help teachers to simplify dense science concepts. Teachers and learners may gain better leverage skills that enable them to strike a balance between words that are used across the curriculum and science content words (Dutro, 2006). A number of examination reports done in Namibia by the Ministry of Education have shown that learners are not able make meaning of subject content (MoE, 2012; MoE, 2013; MoE 2014; MoEAC, 2015; MoEAC, 2016).

The Standardized Achievement Tests (SATs) that have been administered in Namibia do not only reveal the poor performance of learners in Natural sciences but also highlight the difficulty experienced by learners in specific topics such as electricity and magnetism (MoE, 2012; MoE, 2013; MoE 2014; MoEAC, 2015; MoEAC, 2016). Consecutive examiners' reports not only acknowledge this predicament but directly indicate that many learners fail due to their inability to express meaning in this particular topic (MoE, 2012; MoE, 2013; MoE 2014; MoEAC, 2015; MoEAC, 2016), which makes up thirty-eight percent of the total Grade 10 Physical Science curriculum content (MoE, 2010). In the Namibian context, learners understanding and meaning-making in Physical Science are assessed through written work (for example tests, assignments and examinations). The syllabus requires learners to express themselves in English for all written assessments despite it being the second language for the majority of learners. It makes sense that learners will be in a stronger position to make and articulate meaning if they are provided access to the disciplinary discourse by their science teachers.

1.6. Role of English in science learning in Namibia

Wellington and Ireson (2018) acknowledge that one of the important activities in teaching science is to explain ideas without distorting their meanings. According to Wellington and Ireson (2018), studies have shown that language can be a barrier to the acquisition of scientific content. Nutta et al. (2011) explains that Physical Science concepts are even challenging to English First Language (EFL) students and can thus be intimidating to both EFL and English Second Language (ESL) speakers.

In the Namibian context, Physical Science is taught in English – the official Language of Learning and Teaching (LoLT) at upper primary and secondary level, although the majority of Namibian learners are English Second Language speakers (Wolfaardt, 2001). Before the country gained independence in 1990, Afrikaans had been both the national language as well as language of learning and teaching (LoLT). Upon becoming a democracy, English replaced Afrikaans as the national language. It also replaced Afrikaans as the language of learning and teaching from upper primary level (Wolfaardt, 2001; Benjamin, 2004). At that time, English was not widely spoken and only 0.8% of the Namibian population were first language speakers of English (Wolfaardt, 2001). This decision posed challenges for learning and teaching in both rural and urban schools (Harris, 2011) across all subject areas (Wolfaardt, 2001). Since then, researchers have explored the poor performance of learners and also the challenges that teachers face when using English as LoLT in their classrooms (Benjamin, 2004).

Further challenges are experienced when the learners moved from grade three to grade four because the Namibian Ministry of Education (MoE)'s language policy compels the use mother tongue as the LOLT in the first three grades of schooling (MoBESC, 2003). As a result, teachers often resort to using code- switching to ascertain whether learners comprehend concepts (Trewby, 2001). Code-switching happens when a speaker alternates between two or more languages or dialects in one conversation during a lesson (Eldridge, 1996)**.** Code- switching has been observed in all grades in Namibia (Trewby, 2001; Harris, 2011; Liswani, 2016). During code-switching there is a risk that the teacher might not transfer the meaning of concepts exactly in the target language (Skiba, 1997) and this may prevent mutual intelligibility (Eldridge, 1996). Problems arising from language use by teachers during the development of learners' disciplinary discourse could hamper learners' epistemological access to disciplinary knowledge (Gordon, 2009).

1.7. Epistemological access through teacher talk

The Namibian government not only supports admission of learners to schools (formal access) but also compels schools to provide learners with epistemological access to knowledge through the curricula (MoE, 2010). According to Starr (2007) teacher talk is a key tool with which teachers engage students in order for them to gain epistemological access. Literature indicates that teacher talk can enhance or impede learners' acquisition of epistemological access (Morrow, 1994). More specifically, teacher talk may enable or constrain learner's access to scientific literacy (Kelly, 2011).

The Namibian ministry of education through its curriculum reform policies emphasizes the provision of quality science education. One way of achieving this is highlighted in the grade 8-10 science syllabi - the use of teaching approaches that will enhance quality learning in science (MoE, 2010). It is further highlighted that quality learning in science could be achieved if learners have access to scientific literacy (MoE, 2010). Science teachers use talk to mediate written forms of specialized educational knowledge. Teachers' talk in content-based classrooms does not only contribute to learners' language development (Gibbons, 2003) but also facilitates meaning-making and cumulative knowledge-building (Halliday, 1999). Given the complexity of the scientific words (lexicon) it makes sense that science teachers need to be strategic with their classroom talk.

In Namibia, little is known about how teacher talk enables or constrains access to scientific literacy. Studies that have been done in Namibia have focused on such things as the impact of practical activities by Physical Science teachers (Kandjeo-Marenga et.al., 2006), the use of science textbooks in the classroom (Lubben et al., 2002), factors influencing effective teaching of Physical Science (Nakanyala, 2015), the role of everyday contexts in learner-centered teaching in a science a classroom, (Kasanda et al., 2005) and code switching in ESL classrooms (Liswani, 2016). Careful considerations of these reveal a clear gap regarding access to science discourse provided by teacher talk.

Literature suggests that experienced and novice teachers both use language for mediation, but to different extents (Johnson & Dellagnelo, 2013). The study reported on in this thesis, considered the classroom talk of one novice teacher and one experienced teacher. Jensen et al. (2008) categorize novice teachers into two groups: 0-3 years of teaching experience and 4-5 years of teaching experience. Based on their categorization it follows that teachers having 6 or more years of teaching experience may be described as experienced teachers.

Herr (2007) reveals several features for which experienced teachers differ from novices in the teaching of physics. Firstly, experienced teachers have acquired skills that may influence the way they notice, organize, represent and interpret information in their environment. Secondly, in addition to content knowledge, experienced teachers may show superiority in pedagogical knowledge. Thirdly, experienced teachers may work metacognitively - “they can recognize the limit of one’s knowledge, then take steps to remedy the situation” (Herr, 2007, p. 2). Fourth – in physics, experienced teachers may organize their knowledge around core concepts as opposed to the novice who possibly goes no further than describing which equations they would use and how those equations would be manipulated. Fifth - experienced teachers may provide students with learning experiences that may boost their ability to recognize meaningful patterns of information – a skill that may be lacking in novice teachers.

These differences may have a direct influence on whether or not teachers are adequately providing access to disciplinary discourse through their talk. Maton (2014), the seminal author of Legitimation Code Theory, also alludes to the fact that there is a difference in facilitation of meaning-making between a novice and an experienced teacher. This study thus explores the teacher talk of one novice and one experienced Physical Science teacher in Namibia. The analysis of the teacher talk focused on lexical and semantic access. For this study, lexical access is thus viewed from the systemic functional linguistic theory (SFL) perspective while semantic access is considered from the perspective of legitimation code theory

(LCT). These two theories are complementary and have been used by researchers to analyze content-based classroom discourse in terms of cumulative knowledge building (Maton, 2014).

Lexical density can be viewed as a measure of language complexity (Halliday & Martin, 1993). High lexical density is a challenge to learner's access to science discourse. According to Marslen-Wilson et al. (1994) lexical words (content words) give a text its meaning and provide information regarding what the text is about. Jawahar and Dempster (2013) point out that the lexical density of science teacher talk can enhance or impede learners' understanding of the content. However, lexical access alone cannot fully explain the degree to which teacher's talk facilitates meaning-making. The degree of complexity of knowledge, which is an indicator of semantic access to subject content, also present challenges to learners (Blackie, 2014), warranting its consideration in this study. Semantic access allows one to measure the degree of condensation and simplification of the subject content, for the purpose of meaning- making (Evans, 2013). The degree of complexity of language used by the teachers in this study, will provide an indication of the extent to which learners have access to science classroom discourse for the topic of electricity and magnetism.

The Namibian Physical Science syllabus prescribes that teachers simplify and use everyday examples in their teaching so that learners can grasp the subject content (MoE, 2010). As Maton (2013) explains, "teaching involves a repeated pattern exemplifying and unpacking educational knowledge into context dependent and simplified meaning" (p. 9). LCT Semantics uses semantic gravity (the degree to which meaning relates to its context) and sematic density (the degree to which meaning is condensed within such things as symbols, terms, concepts, gestures, actions). Semantic gravity (SG) and semantic density (SD) codes are explained further in Chapter Four. However, this study deals only with the code of semantic density due to its usefulness for exploring access provided by teacher talk in terms of degree of complexity.

1.8. Research problem and significance of the study

1.8.1. Research problem

The topic of electricity and magnetism contains subtopics which have abstract content contributing to learners experiencing difficulties comprehending them (Akursu, 2010). Learners normally memorize these concepts without grasping the content (Akursu, 2010; Borges, 1999; Driver et al., (1994). Grade10 examination synopses have shown that learner's main challenge in this topic is inadequate meaning-making (MoE, 2012; MoE, 2013; MoE, 2014; MoEAC, 2015; MoEAC, 2016). Due to the challenges they face with meaning-making in the topic, many Namibian Grade 10 Physical Science learners fail the topic of electricity and magnetism, and sometimes even the subject of Physical Science (MoE, 2012; MoE, 2013; MoE, 2014; MoEAC, 2015; MoEAC, 2016). This contributes to limiting of access to science careers and to the country's growing need for scientists.

According to Johnson and Dellagnelo (2013) and Agnoletto et al. (2020) the extent to which experienced and novice teachers use language for mediation are different. Thus, exploring the access to disciplinary discourse afforded by the talk of one experienced and one novice teacher was a worthwhile research focus. No naturalistic studies could be found in Namibia that focused on lexical and semantic access afforded by science teacher talk in general, and on the topic of electricity and magnetism in particular. Given the importance of Namibia growing enough scientists for its envisioned development goals and the significance of the topic of electricity and magnetism in the science curriculum, this problematic knowledge gap provided a strong rationale for the current study.

1.8.2. Significance of the study

Poor performance in Mathematics and Physical Science in Namibia causes skills shortages and limits access to scientific careers (Nakanyala, 2015). Literature indicates that poor performance in Physical Science by leaners in Namibia is partly contributed to by the lack of meaning-making in some topics, such as electricity and magnetism (MoE, 2012; MoE, 2013; MoE 2014; MoEAC, 2015; MoEAC, 2016). This study contributes to filling the knowledge gap on ways in which Namibian science teacher talk does or does not, provide access to the disciplinary discourse towards the process of knowledge building by learners. Physical Science teachers and subject advisors may benefit from the results of the study because the findings have relevance to continuing professional development of science teachers. The results from the study also have the potential to inform the work of science teacher training institutions and professional development strategists in Namibia.

1.9. Research objective

The objective of this study was to explore a novice and an experienced Physical Science teacher's talk during grade 10 electricity and magnetism lessons, in terms of the lexical and semantic access they afford.

1.10. Research questions

The research question is:

What is the nature of a novice and experienced Namibian Grade 10 Physical Science teachers' talk during electricity and magnetism lessons in terms of:

a) LCT semantic density?

b) SFL lexical density?

1.11. Structure of the thesis

Following chapter 1, chapter 2 presents the literature review covering the topics of electricity and magnetism, teacher talk, and meaning- making. Chapter 3 focuses on the theoretical framework - with discussions of the theories informing the study: Legitimation code theory (LCT) and Systemic functional linguistics (SFL). Chapter 4 discusses the research design including the orientation of the study, the process of sampling, data collection tools, data preparation, and analysis. It also shows consideration of the issues of ethics, validity and trustworthiness. Chapter 5 presents the results of the study and a related discussion. Chapter 6 includes the conclusion, limitations of the study, and recommendations for further research.

1.10. Concluding remarks

In this chapter, I introduced the background context of the study before discussing science in general, the importance of science graduates for Namibia, the role of English in Namibian science education, and the performance of secondary and tertiary students in science. I then considered challenges to learners' meaning-making in Physical Science. I discussed teacher talk in relation to meaning-making, lexical access, and semantic access. Thereafter, I have outlined the research questions, research goals and objectives of the study. I have also explained the significance of the study in terms of it helping address the knowledge-gap evident from literature. The chapter ended with an outline of this thesis.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

As indicated earlier, the objective of this study was to explore the teacher talk of one novice and one experienced Physical Science teacher during grade 10 electricity and magnetism lessons, in terms of the lexical and semantic access they afford. This chapter reviews some literature relevant to particular key concepts: electricity and magnetism, teacher talk and meaning-making.

2.2. Electricity and magnetism

Electricity and magnetism is central to the study of physics in particular and understanding of science in general (Baigrie, 2007). Electricity and magnetism is also central to understanding technology and society (Ibid). Springer (2016) specifically highlights the important contribution of electricity and magnetism in explaining how electricity power systems work, from the point of generation of electricity up to its distribution. If learners understand the topics of electricity and magnetism they may be motivated to take up further studies or jobs related to electricity and magnetism, such as physics and electrical engineering respectively.

However, researchers reveal that learners have difficulties understanding Electricity and magnetism because the concepts and ideas are counter-intuitive and difficult to appreciate (Ferguson-Hessler & de Jong, 1986; Baigrie, 2007; Sâglam & Millar, 2007). Some studies reveal that difficulties that are experienced by learners in understanding concepts of electricity and magnetism are related to learning and the quality of teaching. This will now be discussed in the next section (2.2.1), before electricity and magnetism the Namibian curriculum is discussed in section 2.2.2.

2.2.1. International studies on teaching and learning of electricity & magnetism

Physical Science includes concepts that are difficult for learners to understand in-primary school (William, 2002), secondary school (Nutta et al., 2011) and even later at university level (Raduta, 2005; Marx, 1998; McDermott & Redish, 1999; Pepper et al., 2012; Liu, 2012). Research has shown that rote learning and misconceptions are some of the reasons contributing to learners' challenges (McDermott & van Zee, 1985; Shipstone et al., 1988; Licht, 1991; McDermott & Shaffer, 1992). One example of a study reporting on learners' relying on rote learning instead of understanding the content was done by Millar and King (1993). More specific studies have also taken place. For example, Millar and King (1993) studied 15-year-old learners using a diagnostic test on simple series circuits, and the results revealed that the learners had limited understanding of voltage.

Due to limited research efforts in electricity and magnetism education (Liu, 2012), the topic has remained problematic to both teachers and leaners. In this regard, studies by Shipstone et al. (1988) and Millar and Beh (2011) are relevant to my study because the authors worked with 15-17 years old learners, which is a similar age group to that of grade 10 Namibian learners who participated in this study. Shipstone et al. (1988), in their study on learners' understanding of basic electrical concepts in five countries (England, France, Netherlands, Sweden and Germany) discovered similar patterns of learning difficulties across student groups in these countries. Learners experienced difficulties making sense of current (flow of charge and energy) and voltage (a force pushing the charged electrons), as well as their relationship.

Millar and Beh (2011) investigated the ability of 15 years old learners to predict voltmeter readings from a parallel circuit. Whilst very few learners could do the predictions, the majority could use the formula V=IR to determine the voltage. Herr (2007) mentions that in physics, experienced teachers tend to organize their knowledge around core concepts, provide learners with learning experiences that help them to recognize meaningful patterns of information, as opposed to the novices who mostly would prefer to solve problems with equations.

A study done by McDermott and Shaffer (1992) reveal that learners had difficulties differentiating between series and parallel circuits when more than two components were used in the circuits. The same study reveals the inability of learners to differentiate between physical lines connecting the elements of the circuit and the electrical connection represented by the lines. The study concluded that learners had confused ideas which resulted in unstable reasoning about the connection of circuit components. Numerous studies (McDermott & van Zee, 1985; Shipstone, et al., 1988; Licht, 1991; McDermott & Shaffer, 1992) disclose that many learners have misconceptions about the amount of current supplied by batteries. They established that learners believe that the amount of current supplied by a battery is always the same, regardless the number of components and the way they are connected in a circuit.

Eylon and Ganiel (1990) discovered that learners believe that a battery acts like a pump that causes the electrons in the wire to circulate and that the wires do not play an active role in the formation of current. Furthermore, a study by Thacker et al. (1999) about current also indicates that learners wrongly understand that charges exclusively originate in the battery. It is evident from these studies that learners experience difficulties and have misconceptions about electricity. Borges and Gilbert (1999) warn that misconceptions impede acquisition of scientific literacy by learners. Michelini et al. (2007) explains that the concepts of electricity and magnetism are abstract and therefore depend on the use of models and analogies. However, in schools where models are not unavailable learners may not be able to observe or feel the consequences of the phenomena regarding the content (ibid). This encourage rote learning by learners and places more weight on verbal explanation of the abstract concepts by the teacher (Michelini et al., 2007).

Studies done by Kock et al. (2014) about the effectiveness of inquiry-based instructional practices on 9 grade 12 learners in the Netherlands concluded that learners even rely on their rote learning when they attempt solving practical questions regarding electric circuits. Similar sentiments are shared by McDermot and Shaffer (1992) who studied the difficulties experienced by students on dc (direct current) circuits when they are exposed to laboratory-based and tutorial-based teaching.

According to Johnstone and Mughol (1978) some students do not easily grasp the meaning of the term resistance and therefore fail to give a qualitative explanation for it. This was revealed by their longitudinal study with 800 pupils of mixed ability from middle secondary to grade six learners, testing how teaching affected learners understanding of resistance. They concluded that learners understanding of resistance can depend largely on the quality of teaching for which the main concern was the lack of pedagogical clarity.

Johnstone and Mughol (1978) suggest that teachers must provide pedagogical clarity in order for the learners to distinguish between definitions of physical quantities on the one hand and relationships between quantities ('laws') on the other. Kilian (2019) reminds us that pedagogical clarity is strongly linked with increases in students' achievements as it helps for example, students to link the topics that are taught to their everyday experiences. Pedagogical clarity entails variables such as communication skills and clarity of explanations, just to mention a few (Kilian, 2019). It is imperative to analyze teacher talk due to it being a common tool used by teachers for providing pedagogical clarity.

2.2.2. Electricity and magnetism subtopics and goals of the Namibian curriculum

Electricity and magnetism form one topic in the Grade 10 Namibian Physical Science syllabus (MoE, 2010). The sub-topics that are listed under this topic of electricity and magnetism are: charge and static electricity, electrical current, potential difference and electrical energy, resistance, electrical circuits (cells and resistors, bulbs in series and parallel), conductors (Ohm's Law), electrical power, electricity in the home, magnetism and magnetic effect of an electrical current (MoE, 2010). The Namibian grade 10 Physical Sciences curriculum (NIED, Ministry of Education [MoE], 2010) requires learners:

- know the basic concepts of charge and current
- know the basic concepts of electric potential
- know and understand the concept resistance, how it is measured and calculated, its units, how resistors can be connected in an electric circuit and factors that influence the magnitude of the resistance of a resistor
- understand the meaning of terms electrical current, potential difference, resistance and Ohm's Law and use them in simple experiments and calculations
- know how to measure and calculate current, voltage and resistance at any points in a circuit
- know power as the rate of doing work, the unit of power as the watt and interpret the watt value of bulbs and other electrical appliances
- know the difference between mains electricity and electricity from batteries and between direct and alternating currents
- know general terminology, conventions and use of electricity in and around the house
- understand magnetism, magnetic properties and uses of magnets
- know the magnetic effect of an electrical current in a straight conductor and a solenoid
- know how to build electromagnets in loudspeakers and electric motors
- know how electrical energy is generated and transmitted in Namibia and understand why this process requires the use of transformers

"In addition to the above theoretical learning requirements, learners are expected to be exposed to or to perform the following practical activities" (Ibid, p. 56-57):

- measure the current at any point in an electrical circuit using an ammeter
- measure the potential difference across an electrical component in a circuit using a voltmeter
- investigate the potential difference across individual components in a circuit

- measure or calculate resistance between any two points (total resistance for 3 resistors in series or in parallel) in a circuit
- investigate the change of the resistance when the conductor: length is increased, diameter is increased and temperature is increased
- investigate ohmic and non-ohmic conductors (including nichrome, copper, eureka wires and light bulbs)
- set up, from circuit diagrams, electrical circuits studied in earlier years involving cells and bulbs and/or resistors in series and in parallel, be able to measure or calculate current at any point in the circuit and the potential difference between any two points
- investigate the relationship between current and voltage in an electrical conductor
- investigate the voltage across and the current through terminals of different appliances in order to calculate their electrical power output by using the formula P= VI (measure in mains electrical circuits not required)
- carry out a survey to find out how electrical energy can be made safer in the school and home (optional)
- practice wiring a three-point pin plug
- investigate and draw the pattern of field lines around a bar magnet and horseshoe magnet (using iron filings and plotting compass)
- investigate the magnetic effect of an electrical current in a straight conductor
- investigate the magnetic field around a bar magnet and a current carrying solenoid
- build an electromagnet
- investigate the difference between the electromagnetic properties of iron and steel
- investigate the difference between a temporary and a permanent magnet
- make a simple electric motor

The above subtopics may be abstract and problematic for learning. Science concepts are semantically dense, belonging to numerous constellations of meanings (Maton & Doran, 2021). As teachers unpack and repack the complicated concepts they need to be aware of their use of language (Johnson & Dellagnelo, 2013). The degree of complexity of knowledge (semantic density) and measure of language complexity (lexical density) are challenges to learner's access to science discourse (Marslen-Wilson et al. (1994); Maton, 2014). Sematic density and lexical density of science teacher talk can thus be viewed as challenges to learners' lexical and semantic access to science discourse.

2.3. Teacher talk

Effective teaching and learning is determined by the way teachers communicate to their learners. One of the means of communication in classrooms is through talking. Wells (1999) alerted us to the fact that talking takes up approximately seventy percent of all classroom discourse in both primary and secondary schools. Classroom discourse is an interaction between teachers and learners or between learners and learners, and may be in the form of text or talk (Hudson, 1980). During classroom discourse, teacher talk must be appropriate and understandable so that learners can make sense of the science content. As Nystrand (1997) puts it, the quality of this classroom discourse is related to the quality of a teacher's facilitation of learning. Therefore, teacher talk plays a major role in providing access to disciplinary discourse and enabling meaning-making of subject content. It is argued by Freebody (2013) that learners' success in science is measured by their written work which to some extent, is related to teachers' talk. One may thus conclude that teacher talk can strongly influence learning and thus the pass rate in school science courses.

Alexander (2008) identifies two types of classroom talk - monologic and dialogic talk. Teachers can use one or both during classroom discourse (Boyd & Markarian, 2011). However, according to Alexander (2008) dialogic talk should be used if a teacher wants to achieve success with regards to facilitation of meaning-making. This is possible because of the five important principles that govern dialogic talk (Ibid). It should be:

- Purposeful (planned and facilitated with clear goals);

- Collective (teachers and learners should attempt learning tasks together as opposed to working fully in isolation);
- Cumulative (teachers and learners integrate their ideas with the ideas of others, into comprehensible lines of thinking)
- Supportive (learners should discuss their ideas freely and help one another in sense-making)
- Reciprocal (Teachers and learners should listen to one another and share ideas).

In support of what Alexander alludes to, Scott (2008) proposes that in order to encourage exploration and development of meaning by learners, a teacher must adopt a dialogic approach as opposed to the authoritative approach which promotes transmitting knowledge to learners (Scott, 2008). Nystrand and Gamoran (1991) explain that teachers who use dialogic talk will ask authentic questions when discussing a topic. These include questions like "How do you know?", which contribute to a dialogic approach (Alexander, 2004). Alexander (2004) further suggests that "Dialogic learning involves students' extended and supported use of talk (involving both teacher-to-student and student-to-student interactions) that includes open-ended questions, reflections, extended exchanges of dialogue, authentic feedback, and building on the ideas of others to collaboratively engage in knowledge construction within a safe learning environment" (p. 31). Monologic talk on the other hand, is controlled by the teacher and paralyses learners' dialogue and interactions (Alexander, 2004). The research reported in this thesis focused on all pedagogic utterances by the teacher, and thus considers both types of talk.

Zhang (2008) and Freebody (2013) point out that teacher talk differs from teacher to teacher and subject to subject. Adding to this, Blackie (2014) highlights that the ways in which novice and experienced teacher classroom talk are different. Maton (2011) explains that semantic shifts by an experience teacher typically differ from those of a novice teacher. Semantic shifts in language are characterized by movement between different degree semantic gravity and different degrees of semantic density over time, and they offer insight into organizing principles of knowledge in classroom practices (Maton, 2013). Changes in semantic gravity and semantic density over time, can be represented in semantic profiles. According to Maton (2013) not everyone is equally proficient of enacting the semantic shifts needed for accomplishing success. Semantic profiles are good yardstick of how teachers, through their talk, pack and unpack meanings in classrooms. However, I could not find studies in the literature, which focused on semantic shifts in Namibian Physical Sciences teachers' classroom talk.

2.4. Meaning-making

Meaning-making can be viewed as the way in which people develop and interpret knowledge in a social manner (Cummins, 1996). Mezirow (1994) defines learning as "the social process of construing and appropriating a new or revised interpretation of the meaning of one's experience as a guide to action" (p. 222). As such, meaning-making not only has implications for learning, but also transformative powers. Merriam and Heuer (1996) indicate that learning is the mechanism for making meaning in life. A science classroom is thus a place where scientific meaning is developed through the interaction between a science teacher and science learners.

Language is recognized as a tool that is used to develop and rehearse meanings between individuals (Scott, 2008), whereas talk is central to the meaning-making process and thus central to learning (Mortimer & Scott, 2003). Scott (2008) indicates that in the process of meaning-making, individual learners must make sense of the talk which surrounds them, recognize and reconstruct the talk in relation to their existing ideas and ways of thinking. A few decades back, Howe et al. (1990) revealed that there were fewer studies done on the analysis of ways in which meaning is developed between teacher and learner than on the student-student interactions in the science classroom. Similarly, although the Namibian Ministry of Education has given some attention to learners' meaning-making on the topic of electricity and magnetism, no studies could be found in the literature on how Namibian science teachers actually facilitate learners' meaning-making.

2.5. Enabling meaning-making through teacher talk

Irrespective of the particular disciplinary discourse, facilitation of meaning-making by teacher talk is entirely dependent on the way the teacher uses language during classroom discourse (Halliday, 1999). Wellington and Ireson (2018) say that language can be a major barrier in learning science, and the English language is no exception. According to Skamp (2004) science has its own language of communication which has technical words with specific meanings. Skamp (2004) explains that “Scientific language also gives scientific meaning to words that may have different usage in everyday language” (p.2). Jawahar (2011) reminds us that scientific English has more technical lexis. Given the complexity of the scientific words (lexicon), it makes sense that science teachers need to be strategic with their classroom talk.

While the emphasis on written exams in Namibia likens it to other contexts in which learners’ success in science is measured by their written work, Freebody (2013) reminds us that learners’ written responses to assessments are shaped by their engagement with teachers’ talk. It is teachers’ talk in content-based classrooms that facilitates meaning-making and cumulative knowledge-building (Halliday, 1999). This reminds us of the need for exploring how Namibian Physical Science teachers’ talk contributes to meaning-making for electricity and magnetism, as outlined in Chapter One.

2.6. Concluding remarks

In this Chapter, I discussed the topic of electricity and magnetism. Some international studies were identified which point out details of learners’ difficulties with the content related to the topic of electricity and magnetism. I also briefly discussed the topic of electricity and magnetism in the Namibian Physical Science curriculum. Meaning-making in the topic of electricity and magnetism in the Namibian context was also discussed. I then elaborated on teacher talk in relation to meaning-making. We will now turn our attention to the theories framing the study – LCT and SFL.

CHAPTER 3: THEORETICAL AND ANALYTICAL FRAMEWORK

3.1. Introduction

In this chapter I discuss the theories that inform the study -Legitimation Code theory (LCT) and Systematic Functional Linguistics (SFL). In addition to explaining the theories more broadly, I elaborate on the relevant concepts that are provided by the two theories which guided me in developing a semantic density translation tool, for this study. Since LCT expands on the work of Bernstein and Bourdieu, a brief description of their theories is first provided. The complementarity between the two theories is based on the evolutionary dialogue between them. I conclude the chapter by substantiating why the study focuses on the lexical and semantic access afforded by teacher talk.

3.2. Legitimation Code Theory (LCT)

Legitimation Code Theory as proposed by Professor Karl Maton, has as its roots in social realism (Blackie, 2014). Social realism reveals that although knowledge is socially constructed, it is based on an external reality which has effects that can be explored (Macnaught et al., 2013). Social realism offers a language to theorize the different forms of external interest and to explore their effects for cumulative knowledge building over time (ibid). It links knowledge to forms of external interest that has their focus on inequalities in social class while paying very little attention to the forms of internal interest (cognitive interest), which deal with the production and acquisition of knowledge itself (Maton & Moore, 2010). Maton (2014) explains that the issue of the nature of cumulative knowledge building and its enablement in practice remains opaque.

Maton and Moore (2010) aver that knowledge should be linked to both external and internal interests. According to Maton and Moore (2010) different forms taken by different structures of knowledge construction have different effects. Research related to internal interest is exemplified by the professional roles of teachers in knowledge building and how pupils can access different forms of knowledge (Maton & Moore, 2010). Legitimation code theory provides a conceptual framework that provides relevant analytical tools such as semantics (table 3.1), that could be used to characterize cumulative knowledge building related to both external and internal interests (Maton & Moore, 2010). It also builds upon Bernstein's code theory and Bourdieu's field theory (Maton, 2013). Maton (2013) describes Bernstein's work is based on code sociology (codes and coding orientations) whereas Bourdieu's is based on logic of context and actors dispositions.

The socio-linguistics theory of language code by Bernstein refers to codes as collections of organizing principles behind the language used by people or social groups (Littlejohn, 2002). Bernstein (1971) as cited in Young (2002) states that people assign meaning to things about which they are speaking. Legitimation code theory extends Bernstein's code theory by providing different codes (indicated in table 3.1) for analysis of educational practices. In this study, semantic density - one code of LCT's semantics dimension, was utilised to characterize pedagogic practices of teacher talk in a Physical Science classroom. LCT's semantics is further discussed in section 3.2.1.

Bourdieu's field theory amplifies the aforementioned idea of social groupings and interactions. The theory explains that the fields, which are governed by rules, comprises of people and their social positions in that field (Maclean, Harvey & Kling, 2014). These positions are hierarchical categories where superior and peripheral positions are depicted (Bourdieu, 2005), for example the teacher and the learners in a classroom. LCT also provides a language of legitimation for the type of knowledge that is created and by whom, in a particular field (Blackie, 2014). This is not the focus of the current study, but could be explored via the dimension of specialization (with its epistemic and social relations codes, as shown in table table 3.1) of LCT.

It is clear from the above discussions that LCT offers a framework for investigating and shaping knowledge practices with the purpose of advancing social justice and knowledge building (Maton, 2011). Researchers can amongst other things, ascertain if the disciplinary discourse afforded through teacher-talk enables or constrains knowledge building during lessons. The theory has been successfully applied in areas such as sociology, linguistics, philosophy, anthropology, natural sciences, and cultural studies (Maton, 2011).

The current study characterizes how experienced and novice Physical Science teachers who are dealing with syllabi, facilitate meaning-making though their talk in the Physical Science classrooms. Meaning-making is problematic for learner's achievements at secondary schools and their advancement to tertiary education for pursuing science (MoEAC, 2016). The position of a science teacher as a facilitator of meaning-making and acquisition of specialized field of knowledge, enjoys superior status and control (Scott, 2008). In the formal science education set-up, the teacher who is the implementer of the curriculum should successfully facilitate acquisition of science knowledge by the learners. Failing to do so means that the learners will not perform well in science subjects such as Physical Science. In turn, there will likely be a shortage of science graduates to take up science-related jobs. This may also obscure societal achievement and enhance the continuation of unequal and unjust societies.

According to Maton (2013), LCT comprises five principal dimensions: Autonomy, Density, Semantics, Specialization and Temporality. These dimensions offer concepts for analyzing particular sets of organizing principles (referred to as codes) that underly practices. Table 3.1 summarizes the five dimensions of LCT, their referents and concepts (Maton, 2014). This study focused on the dimension of semantics, and the concept of semantic density in particular.

Table 3.1: Summary of LCT's dimensions, referents and related concepts (Maton, 2014, p.31)

Dimensions	**Referents**	**Concepts**
Autonomy	External relations	Positional autonomy Relational autonomy
Density	Internal relation	Material density Word density

Semantics	Meaning	Semantic density Semantic gravity
Specialization	Symbolic/social	Epistemic relation Social relation
Temporality	Time	Temporal position Temporal orientation

3.2.1. LCT Semantics

LCT semantics involves the concepts of semantic density and semantic gravity (Maton, 2013). According to Maton (2013) semantic density (SD) refers to the degree of condensation of meaning within socio-cultural practices (symbols, terms, concepts, phrases, expressions, gestures, actions, clothing etc.) while semantic gravity (SG) refers to the degree to which meaning relates to its context. Although the semantic dimension of LCT involves semantic gravity and semantic density, this study focuses on semantic density only as necessitated by the two research sub-questions. Maton (2014) and Hugo (2014) confirm that semantic density and semantic gravity are independent of each other and can be used together or individually to analyze knowledge-building practices.

Maton (2013) explains that a stronger semantic density (SD+) indicates that more meanings are condensed within practices while a weaker semantic density (SD-) indicates that fewer meanings are condensed within practices. He clarifies condensation of meaning as being process whereby relationships are created between meanings of concepts within practices. An example could be the science concept "Power" which is related to the associated meaning of "work over time", and "Work" is in turn associated with the meaning: "change in energy". Change in energy is again linked to the meanings of kinetic and potential energy. According to Maton (2013) this process creates a "constellation" of meanings which can continue indefinitely.

A semantically dense science concept such as "Power" in the above analogy is called a solitary note (Maton, 2013). Moving back and forth between the solitary note and concepts containing greater or fewer meanings, creates a continuum of semantic density strengths (Maton, 2013). This continuum allows for increasing or decreasing strengthening semantic density. For example, the movement from a scientific concept condensing a smaller number of meanings towards it covering a greater range of meanings, is described as increasing semantic density (SD↑). On the other hand, the movement from a scientific concept condensing many meanings to it having fewer meanings, is described as weakening semantic density (SD↓) (Maton, 2013).

The forms of semantic density are varied depending on the type of practice and context (Blackie, 2014). The concept of semantic density has been used to analyze pedagogic practices across various disciplines such as journalism, nursing, English and history (Blackie, 2014). While there are studies available that have used both concepts of semantic gravity and semantic density together, there are also other studies that employed either one of them. One example is the study by Steenkamp et al. (2021) from the University of Stellenbosch in South Africa which used semantic gravity to analyze assessments in introductory physics class. Furthermore, Bratland and El-Ghami (2021) used semantic gravity to investigate the types of knowledge practices that characterized students' research and development papers for a recent teacher education reform in Norway.

3.2.2. Semantic profiling

The strengthening and weakening of semantic density over time can be presented on a graph as a semantic profile. Semantic profiles aid in understanding how knowledge building occurs over time in classroom practices (Maton, 2013). Maton (2013) explains that "teaching involves a repeated pattern unpacking educational knowledge into simplified meaning" (p. 9). This is aligned to the Namibian Physical Science syllabus prescription that teachers must be able to simplify and use everyday examples when they teach in order for learners to grasp the subject content (MoEAC, 2010). Figure 3.1 shows a profile of teacher talk known as a downward escalator.

The semantic density profile is characterized by repeated movements from highly condensed ideas (SD+) towards simplified meanings (SD-) (Maton, 2013). Upward escalators are also possible. Pedagogic practices that are exemplified by escalators, such as the ones in figure 3.1, are indicative of a teacher being able to unpack concepts into simple components (decreasing semantic density) (Hugo, 2014). However, the teacher then fails to link the different concepts again or to pack the concept back into more complex issues (ibid). Hugo (2014) reminds us that although teachers need to unpack dense concepts into simple components for learners to be able to understand them, the concepts ought to then be used with related concepts for the learners to understand more complicated processes.

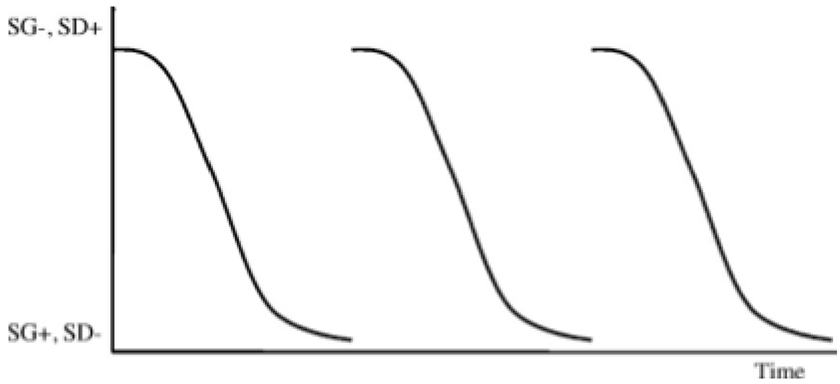

Figure 3.1: *Example 1 of a "Downward Escalator" semantic profile of a teacher talk (Maton, 2013).*

Figure 3.2 illustrates the differences between flatlines (A1 and A2) and a sematic wave (B). A1 is a high semantic flatline while A2 is a low semantic flatline (Maton, 2017). Pedagogic practices depicting low semantic flatlines are characterized for example, by practices where concepts have fewer associated meanings, whereas high semantic flatlines show practices where concepts maintain a broader range of meanings (Brooke, 2019) and the discourse has complex epistemological constellations of meanings (Maton, 2014). Wave B follows the movement from complex to simplified content and back towards complex content - showing a higher semantic range. A1 and A2 on the other hand, have very low semantic ranges (ibid). According to Maton (2013), waving across a higher semantic range is more beneficial to knowledge-building than flatlines or upward/downward escalators.

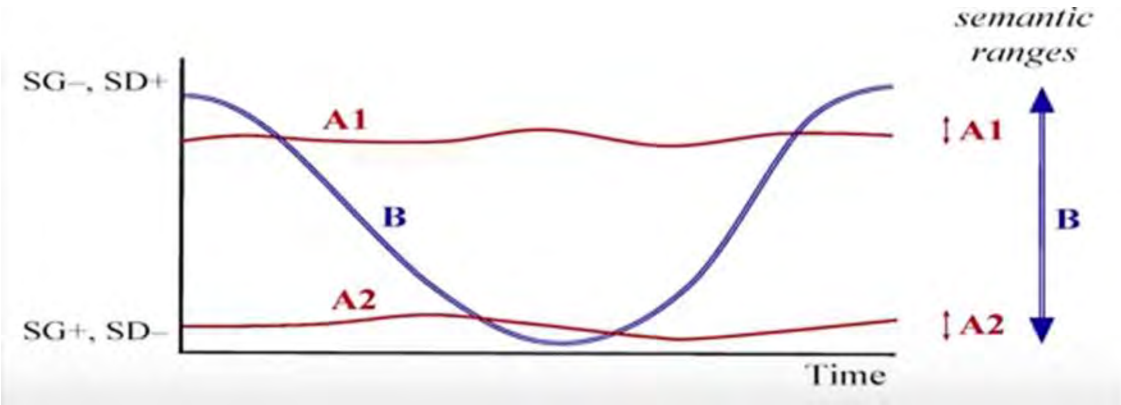

Figure 3.2: *Example of a semantic wave and flatlines. (Maton, 2017).*

In Figure 3.3, the semantic profile starts relatively high, with a question that is abstract and has more meanings condensed. Semantic density is decreased by narrowing meanings to more specific everyday ones. During "repacking", meaning is repacked into a concept with more constellations of meanings, thus increasing SD (Maton, 2013). Maton (2013) further explains that repacking is as important as the "unpacking phase" as it allows learners to use concepts for understanding more complex issues (Maton, 2013). As per the Namibian syllabus (MoEAC, 2010), the teacher must simplify dense science concepts for learners in order for them understand the content. The same syllabus also stipulates that the teachers must work from simple to complex sequencing (MoEAC, 2010). The two teaching strategies are in line with Maton's work. The simplified concepts will be applied to build complexity with regards to science content. A typical example is when a teacher has to simplify the concepts of voltage and current in order for the learners to be able to apply these simplified terms to explain or calculate resistance or to interpret the current-voltage graph. The talk then descends the semantic scale, undergoing unpacking again. In this case the teacher provides examples of the key concept to make meaning more specific. Downwards and upwards shifts in the semantic profile enable the simplification of knowledge through time, a crucial condition for cumulative knowledge-building (Maton, 2013). Maton (2017) reports that "semantic waves can take many forms- in terms of range, directional shifts, entry and exit points and threshold" (p. 17). As mentioned earlier, Maton (2014) suggests that novice and expert teacher talk are unlikely to produce similar semantic waves.

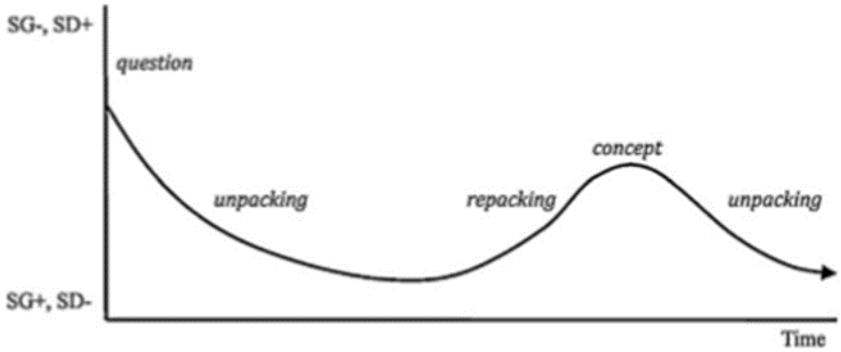

Figure 3.3: *Example of semantic waves in Grade 11 History teaching (Maton, 2013).*

Semantic density has been used together with semantic gravity to analyze cumulative knowledge building and learning achievements across different areas of natural science education: Biology (Macnaught et al., 2013; Maton, 2013), Physics (Georgiou, 2014) and Chemistry (Blackie, 2014). Students' achievement in science subjects is directly related to how their knowledge is organized in terms of form and content (Georgiou, 2014). Georgiou and her colleagues quantitatively analyzed tertiary student responses to a thermal physics question. According to Georgiou (2014), what makes a good answer can be clarified by looking at the strength and ranges of semantic gravity. Their study revealed different ranges of semantic gravity in students' responses to the question. Brooke (2019) has done research on teacher talk in the content and language integrated learning classroom using semantic gravity waving. The findings indicated that semantic gravity waving could theoretically facilitate student comprehension of content better and could be a useful tool for planning of teacher talk. A study by Maton (2013) analyzed textual responses to a grade 11 biology examination question. The results identified a low scoring text and a high scoring text. Low scoring text produced flatlines whiles the high scoring text produced semantic waves (see Figure. 3.2 for examples).

The study by Blackie (2014) relates to my study, as it deals with teaching practice. Blackie (2014) used LCT semantics (semantic gravity and semantic density) as a framework to analyze and improve her own practice in the teaching of Chemistry. From the results, she became aware of the kinds of complexities associated with the different sections of chemistry. She was able to identify the cause of her students' confusion and address them accordingly. The use of SG and SD also helped her with the pacing of her teaching. Maton and Doran (2017) distinguish between epistemic and axiological SD and SG. According to Maton and Doran (2017) epistemic SG and SD relies on empirical data or definitions through knowledge enactment in practice and research, while axiological SG and SD are rooted in affective, aesthetic, ethical, political and moral stance. It is epistemic SD that is taken forward in this study as opposed to axiological SD, since it relates to knowledge-enactment.

3.3. Systemic Functional Linguistics (SFL)

SFL is a theory that was developed by Michael Halliday in the early 1970's (Kress & Leeuwen, 2001). The theory considers language to be a social semiotic resource that people use for accomplishing their purposes by creating meaning in context (Halliday, 1993). This language, according to Gibbons (2003), carries simultaneous meanings: the ideational meaning or field (what is being talked or written about), the interpersonal meaning or tenor (the relationship between the speakers or writer, and reader), and the textual meaning or mode (spoken and written language). The three types of meaning are collectively known as 'metafunctions' (Halliday, 1993).

In this study, the field is the topic of electricity and magnetism in Physical Science; the mode is the teacher talk'; and the tenor is the relationship between teacher and learners. The study operationalizes lexical density as an analytical tool for exploring the lexical access afforded by teacher talk. Some earlier studies that involved calculating lexical density include one by Stanley and Stevenson (2017) which focused on an English Language classroom, and one by Elliot (2009), which focused on a science classroom. The study by Stanley and Stevenson (2017) has scrutinized the teacher talk of three novice teachers from a critical intelligibility viewpoint. The study revealed the difficulties that novice teachers have in framing their language appropriately. Elliot (2009) found that teacher talk with content specific vocabulary is a positive predictor learner's learning outcomes.

Lexical density refers to the number of content carrying words per clause (Halliday 1993, in Jawahar, 2011). Another formula that is used to calculate the lexical density is the number of content words divided by the total of words x 100.

$$\textbf{Lexical density} = \frac{\textit{Number of content words}}{\textit{Total words}} \textbf{ X 100\%}$$

The above formula is known as Ure's method (Al-Wahly, 2019). This formula has been adopted by well-known researchers in lingusitics such as Linnarud (1976), Stubbs (2002), Eggins (2004), Castello (2008) and Johansson (2009). It is evident from this formula that lexical density increases with the use of more content words and vice versa. According to Halliday and Martin (1993) lexical density can be viewed as a measure of language complexity. The greater the lexical density of science teacher talk, the greater the difficulty experienced by students in understanding it (Jawahar & Dempster, 2013). Jawahar (2011) used an alternative formula, which my study also embraces:

$$\textbf{Lexical density} = \frac{\textit{Number of Science content words}}{\textit{Total number of words}} \textbf{ X 100\%}$$

In determining the lexical density, he made three adaptations to the formula. Firstly, the calculations are based on teacher utterances rather than the learners'. This is because he focused on exploring teacher talk. Secondly, the calculation of lexical density is based on content carrying words per teacher utterance rather than per clause or sentence because the teachers did not talk in neat clause structures and so what is perceived as a clause or sentence in the data would depend on the transcriber at that time, thus weakening validity. Thirdly, because the study dealt with the field of Physical Science, his calculations of lexical density considered the number of science content words rather than the general English content carrying words. The justifications he provided are also relevant to the current study, hence this study adopting his formula for lexical density.

3.4. Sense relations

According to Hurford et al. (2007) the sense of an expression in a language is a semantic relationship of an expression with other expressions in the language. As discussed earlier, SFL considers language to be a social semiotic system of interaction where users shape and interpret meanings (Halliday, 1975). Those meanings are communicated via the three complementary metafunctions: ideational, interpersonal and textual (Halliday, 1975). Central to this study is the ideational metafunction. This metafunction entails cohesive through various sense relations (Taverniers, 2011). In this study, I have used four sense relations: hyponymy, synonymy, antonymy and homonymy to inform the coding of science content words in the teacher utterances. Science relations helped me to identify science content words which were not immediately recognized as such.

According to Matzner (2016), hyponymy is a linguistic sense relation that signifies words that belong to a subset whose elements are together summarized by a hypernym. Matzner (2016) gives examples of individual hyponyms like ‘tree,' 'flower,' 'bush’ being cohyponyms of the hypernym 'plant.' Examples relevant to the current study are ‘alternating current’, and ‘direct current’ being cohyponyms of the hypernym ‘current’. Similarly, ‘circuit’ is a hypernym to cohypernyms of ‘series’ and ‘parallel’. Barrière (2004) points out that the use of hyponyms could help Physical Science teachers’ explanations of new science concepts in the classroom.

Synonymy is a linguistic sense relation that exists between lexical words having a shared meaning and identity to the extent that they can be substituted for each other in either direction or interchangeably (Matthews, 2007). Similarly, Greenbaum (1996) refers to synonymy as expressions that are identical or similar in meaning and that can be used interchangeably in at least one context. Geeraerts (2010) distinguish between two types of synonymy: absolute synonymy and partial synonymy. According to Geeraerts (2010) the pairs ‘jail’ and ‘prison’; and ‘autumn’ and ‘fall’ are examples of absolute synonyms because they have exactly the same meaning. They can also be used interchangeably as per Greenbaum (1996) definition. An example from the data in this study is the pair ‘dry cells’ and ‘battery’. Partial synonyms do not have exactly the same meaning and may not be used interchangeably (Geeraerts, 2010). Examples of partial synonyms given by Geeraerts (2010) are ‘abdomen’, ‘belly’ and ‘stomach’ - they do not have exactly the same meaning and may not be used interchangeably. An example of partial synonyms from the data in this study is the pair 'energy' and 'power'.

According to Croft and Cruse (2004), antonymy refers to the relationship between words with opposite meaning such as 'long' and 'short', 'fast' and 'slow', 'hot' and 'cold'. Examples relevant to this study are 'positive' and 'negative' with reference to electrical charges. Another example from this study is 'direct' proportionality and 'indirect' proportionality when the teacher unpacks/ explains the relationship between resistance, voltage and current using graphs.

Meronymy is a term that is used to designate a part-whole relationship between lexical items (Saeed, 2003). In semantics, a meronym is a word that signifies an integral part or a member of something (Nordquist, 2009). 'Finger' is a meronym of 'hand' (Murphy, 2003), 'apple' is a meronym of 'apple tree' (Nordquist, 2009) and 'nose' is a meronym of 'face' (Saeed, 2003). Physical Sciences have many words that name parts of things, and teachers make use of meronymy to show the relationship between the whole and its parts. Examples relevant to the current study are the 'resistor', 'bulb' and 'switch' all being meronyms of 'circuit'. The SFL sense relations contribute a significant part of the coding and analysis in this study of teacher talk in the Namibian Physical Science teachers' classroom.

3.5. Historical links, complementarity and collaboration between LCT and SFL

The links between LCT and SFL can be traced through the dialogue that existed between theorists expanding on them from the 1960s. LCT is based in part on Bernstein's code theory which enjoys a long and constructive historical relationship with SFL. The rise of LCT from code theory has enhanced the focus, the form and the dynamics of exchanges with SFL, which eventually culminated in numerous collaborative studies exploring knowledge-building in various disciplines (Maton, Hood and Shay, 2016).

A number of scholars who have used both theories have presented papers at International LCT conferences and SFL congresses. Maton, Martin and Matruglio (2016) reveal that studies which endorse both LCT and SFL are increasing. The theories are both used in disciplines such as law, art, education and politics (Maton, Martin & Matruglio, 2016). They further highlight that such studies are applying the sociological and linguistic approaches that are offered by the theories to give complementary insights into different disciplines. According to Maton (2013), SFL and LCT are being used cooperatively in the analyses of shared data. Both theories provide specific tools for analyzing data.

The two theories are complementary for exploring cumulative knowledge-building in classrooms (Maton, 2013). For example, during a three-year 'Disciplinarily, Knowledge and Schooling' (DISKS) research project at the University of Sydney, Australia. Martin (2013) used the SFL concept of field and mode to analyze classroom discourse. His study involved an analysis of knowledge-building in Secondary School Biology and History through teacher talk while Maton (2013) used LCT dimensions (Semantic density and Semantic gravity) to analyze teacher talk in History and Biology classrooms for cumulative knowledge-by illustrating semantic wave profiles. The research project's aims were to scrutinize the bases of knowledge-building in secondary school classrooms and to explore the differences across different kinds of subjects in the school curriculum (Maton, Martin & Matruglio, 2016). By doing so the researchers further aimed at developing pedagogic practices that could enable the process of cumulative knowledge-building (Maton, Martin & Matruglio, 2016).

A recent chemistry study was undertaken by Cranwell and Whiteside (2020) which produced SD and SG wave profiles of teachers during the discussions of electrophilic and aromatic substitution. My study uses the SFL's lexical density (LD) and LCT's Semantic density (SD) as tools to analyze the data related to teacher's talk with the aim of exploring a novice and an experienced Physical Science teacher's talk during grade 10 electricity and magnetism lessons, in terms of the lexical and semantic access they afford.

3.6. Lexical and semantic access

The Namibian Grade 10 Physical Science syllabus recommends that teachers use everyday language to simplify and contextualize subject content so that learners can grasp the subject content (MoE, 2010). Leaners' mental lexicon changes and grows as they come across new words in a classroom. Science language has its own difficult words and the teacher must help learners to enhance their scientific vocabulary and understanding of subject content. According to Scott (2008) the teacher's role is to develop new understandings or meanings in the science classroom. Lemke (1990) explains that development of these meanings in learners is facilitated by the way teachers use language in their talk. Further to this, Scott (2008) alerts that science teachers afford access to science discourse for learners, through their provision of thematic patterns of semantic relationships which constitute scientific content.

Lexical access is fundamental to speech and writing comprehension and it enables us to access words and their related meanings, or how meanings are expressed in context in our minds during listening and reading (Vakoch & Wurm ,1997 ; Gleason & Bernstein, 1998). Lexical access involves finding words that fulfill the semantic requirements of a message (Gordon & Baum, 1994). Complexity of communication in language may limit lexical access (Levelt, 1989). This study focused on lexical access and used SFL's lexical density as an analytical tool to measure the degree of lexical access afforded by the teachers talk during electricity and magnetism lessons.

According to Marslen-Wilson et al. (1994) lexical words (content words) give a text its meaning and provide information regarding what the text is about. Lexical density can be viewed as a measure of language complexity (Halliday & Martin, 1993). According to Jawahar & Dempster (2013) the lexical density of science teacher talk can enhance or impede learners' understanding of the content. Therefore, a higher LD will pose challenge to learners gaining access to science discourse. However, lexical access alone cannot fully explain the degree to which teacher's talk facilitates meaning. According to DeBoer (1999) context-dependence and simplification of meaning are some of the requirements for facilitation of meaning by teachers (DeBoer, 1999).

In order to explore the semantic access afforded by the teacher talk in this study, I traced changes in the degree of condensation and simplification of the subject content in the talk at various points in the lessons. While traditional linguistics views semantics as the study of meaning of words (DeBoer, 1999), this study is theoretically framed by LCT Semantics which deals which is concerned with the study and analysis of meaning in relation to knowledge-building. Therefore, the semantic access afforded by teacher talk that is referred to in this study, is viewed and discussed solely from the LCT perspective. As alluded to earlier, LCT semantics views meaning in terms of how language is condensed (language complexity) to make meaning and how strongly bound it is to context (semantic gravity). However, this study is more concerned with the complexity (semantic density) of the subject matter as opposed to looking at the context dependency (semantic gravity), and so only are SD features considered in the research methodology in Chapter Four.

3.7. Concluding remarks

In this Chapter, I have discussed the two theories that framed this study: LCT and SFL. Their complementarity and historical links in research have been acknowledged. The analytical tools provided by LCT and SFL have also been discussed in detail: semantic density (from LCT) and lexical density (from SFL). I have also looked at SFL sense relations due to their importance in the coding process for identifying science content words. The chapter concludes with the discussion of how LCT semantic density provides a perspective on semantic access afforded by teacher talk, and SFL lexical density provides a perspective on lexical access afforded by teacher talk.

CHAPTER 4: RESEARCH METHODOLOGY

4.1. Introduction

Research methodology outlines how a research study is designed, and describes strategies as well as the logic behind their selection, for answering the research questions (Kothari, 2004 & Wilson, 2013). In this chapter I discuss the overall research methodology by focusing on the following: research orientation and paradigm, research methods, research site and participants; sample and sampling technique; data collection tools; data preparation and data analysis. The chapter also elaborates on issues related to validity, trustworthiness and ethics.

The study was framed by two complementary theories - LCT and SFL that guided the exploration of lexical and semantic access for the topic of electricity and magnetism afforded by one novice and one experienced Namibian teachers' talk. As indicated in section 3.2, the two theories have been used in previous case studies to analyze cumulative knowledge-building in classroom discourse. The research method employed in this study is also a case study. The case study is underpinned by the interpretive research paradigm and adopts a mixed method approach.

4.2. Research orientation and paradigm

The way we conduct research is influenced by how we acquire knowledge (epistemology) and how we view reality (ontology) in the research process (Babbie & Mouton, 2001). Variations in both epistemology and ontology give rise to different research paradigms that influence the kind of question asked, the kind of data collected, and how the data are interpreted (Bertram & Christiansen, 2014). Bertram and Christiansen (2014, p. 24-28) identify three key research paradigms:

- Post-positivist paradigm, where researchers seeks to describe, control and predict how the natural and the social worlds operates. This assumes there is an objective reality (realist ontology) and that researchers come to understand through their objective experiences (objective epistemology).
- Interpretive paradigm, where researchers try to describe and understand how people make sense of their worlds, and how they make meaning of their actions.

This assumes that each situation has its own reality (relativist ontology) and researchers come to understand it through their subjective experiences (subjectivist epistemology).

- Critical paradigm, where researchers see reality as shaped by social, political, cultural, economic and other dynamics. Whilst this is usually a form of objective reality (realist ontology), researchers can only come to know this reality through their own subjective understanding (subjectivist epistemology). The emphasis in this paradigm is on positive change.

The objective of this study is to explore the semantic and lexical access afforded by teacher talk of a novice and an experienced teacher in a Namibian context, for the topics of electricity and magnetism. Based on the above paradigm breakdown, this places this study in the interpretive research paradigm, as it is attempting to make sense of a particular situation (subjective/relativist ontology) from a subjective understanding (subjectivist epistemology).

It needs to be said that LCT research usually falls under the critical paradigm as it recognizes an objective reality. However, instead of using LCT in a traditional sense to examine any underpinning objective reality, this study simply uses one relevant aspect of the theory (semantic density) due to its usefulness as an analytical tool towards addressing the research question. Hence the categorization of this study as being situated in the interpretive paradigm, despite drawing on what could be referred to as a critical realist theory.

4.3. Research methods

The research method used in this study is mixed methods. According to Creswell (2014), mixed method research helps answer questions that cannot be answered by qualitative or quantitative approaches alone. Creswell (2014) explains that mixed method research is a procedure that involves the collection, analysis and mixing of both qualitative and quantitative data in a single study or a multiphase study. The research question guiding this study required the use of both qualitative and quantitative data analysis. The data was collected qualitatively, but it was analyzed both quantitatively and qualitatively. This study is thus a mixed method case study that was used to explore semantic and lexical access for the topics of electricity and magnetism afforded by Namibian Physical Science teachers' talk.

Case studies may use a combination of both qualitative and quantitative data (Bertram & Christiansen, 2014). According to Wilson (2013) a case study is an appropriate approach for school-based research as it provides detailed knowledge about a single or small number of cases. The two complementary theories, LCT and SFL, which informed the study have also been used by Maton (2013) and Martin (2013) in case studies, as already explained. Despite the ongoing criticism of the results of case studies not being generalizable – they are a means to capture reality (Murphy, 2014) or retain more of the "noise" of real-life situations which may not be captured through many other types of research (Hodkinson & Hodkinson, 2001). The current study involved no intention to generalize the findings but to contribute to our understanding of a classroom phenomenon in a classroom – the semantic and lexical access afforded by teacher talk of one novice and one experienced Physical Science teacher for the topics of electricity and magnetism.

4.4. Sampling techniques

Sampling is a process by which a researcher makes decisions about selection of people, settings, events or behaviors that must be included in the study (Bertram & Christiansen, 2014). There are two broad types of sampling – probability sampling and non-probability sampling (Taherdoost, 2016). During probability sampling every single element or member of the population has equal opportunity to be selected. Non-probability sampling on the other hand (which includes convenience; purposive and quota sampling) involves elements in the population not having equal opportunity to be selected (Taherdoost, 2016).

Purposive sampling is a sampling technique in which researchers select using their judgment, the elements or participants of a study (Pillai & Urvashi, 2020). Cohen et al. (2011) state that purposive sampling allows the researchers to build a sample that is satisfactory to their specific needs, to make comparisons and to focus and engage deeply with their cases. The current study did not only compare the semantic density profiles that were created by the teacher talk of a novice and an experienced teacher, but also aimed for an in-depth understanding of the teacher talk in relation to scientific meaning-making in the classroom. Purposive sampling was used to select the teachers and the schools. The two teachers were selected on the basis of the number of years teaching Physical Science. The schools were selected on the basis that they are situated in the Region that have learners who have problems with meaning-making in the national examination according to examiner reports (MoE, 2012; MoE, 2013; MoE 2014; MoE, 2015; MoEAC, 2016; MoEAC, 2017; MoEAC, 2018).

4.5. Research site and participants

The study was carried out in the Oshana region located in the Northern part of Namibia. The reports by the Namibian Ministry of Education (MoE, 2012; MoE, 2013; MoE 2014; MoE, 2015; MoEAC, 2016; MoEAC, 2017; MoEAC, 2018) specified that learners in schools in the northern part of Namibia experience more problems related to meaning-making in the grade 10 final examinations. The study was done at two Government schools (School X and School Z) in the Oshakati circuit. The two schools are less than 50 meters away from one another. They both offer education from grade 8 to 12. Each school is equipped with a Physical Science laboratory. English is a second language at both schools while learners study Oshindonga or Oshikwanyama as the First Language. The majority of learners are Oshiwambo language speakers. The Oshiwambo language consists of the following dialects: Oshikwanyama, Oshikwambi, Oshingandjera, Oshikwaluudhi, Oshimbandja and Oshikolokadhi. All dialects are spoken at the two schools.

The two participating teachers were selected based on different years of Grade 10 Physical Science teaching experience. One is a novice teacher while the other one is an experienced teacher. Jensen et al. (2008) categorized novice teachers as teachers having between 0 and 3 years of teaching experience. The selected novice teacher (from school X) was in the 3rd year of teaching of Physical Science while the experienced teacher (from school Z) has 12 years of Physical Science teaching experience. I had initially planned on a scenario with both teachers from one school, but this may have adversely impacted on the trustworthiness of the study had the two participants discussed their teaching practice (and more specifically, their language use).

4.6. Data collection methods

In order to obtain the relevant data for the discourse analysis required to answer the research question, one novice and one experienced Physical Sciences teacher needed to be audio recorded while teaching Grade 10 E&M. Observation and recording are classified as passive data collection methods (Esomar, 2009). Video and/or audio recordings are used in various disciplines to document processes, procedures and interactions (FitzGerald et al., 2012). Bloor and Wood (2009) defines audio recording as the recording of sound such as speech. Audio recording has replaced researchers' handwritten notes within qualitative research (Bloor & Wood, 2009). According to Tessier (2012) audio recording increases reliability, and reduces cost and loss of data. The current study employed one data collection tool - audio recording of teacher talk.

Jawahar (2011) warns that presence of the outside observer to the learners and teachers in the classroom has the potential to reduce the trustworthiness of the data. I have attended 20 lessons in total, all covering the topics of electricity and magnetism. The first 4 lessons (2 for each teacher) were for the purpose of acclimatizing the teacher and learners to the presence of myself (an outside observer), and thus no recording was done. A total of 16 lessons were then audio recorded - eight lessons for each teacher. However, only 14 of the 16 recorded lessons were then transcribed. This is because the first one by each teacher was used to test the quality of recording. According to Moore and Llompart (2017), researchers must develop trust in participants in the presence of their recording equipment. My presence in the class, as an outside observer, might have caused both teachers and learners to behave or talk differently, negatively impacting on validity of the data prior to the data collection for answering the research questions.

To reduce the impact of my presence in the classroom, I acclimatized the teachers and learners by attending two lessons for each teacher prior to any recordings. This was followed by recording two lessons (1 in each class). The aim was also to continue acclimatizing the teachers and learners to my presence while also testing the effectiveness of the recording equipment. Moore and Llompart (2017) suggest that novice researchers align the type of recording equipment to the environment. I took cognizance of the possibility that learners may be noisy and towards the goal of clear audibility in recording, I opted to use the DVT6010 eight gigabytes Phillips audio recorder that has three microphones (one directional center microphone and two high-quality omnidirectional stereo microphones). The recorder also had a built-in motion sensor, a voice tracer and 15 m zoom mic. Due to its high quality recording capability there was no need to restrict the teacher from moving around the classroom, allowing them to teach as they naturally would in the absence of recording equipment. The recorder was placed on the teacher's table to avoid learners' being distracted by the equipment. The teacher stopped the recording at the end of each lesson.

4.7. Data preparation and analysis

The research steps following data collection are data preparation and data analysis. According to Kothari (2004) collected data has to be prepared and analyzed in line with the research plan. Data preparation involves activities such as editing; coding; classification, tabulation and graphical presentation of collected data in preparation for the process of analysis (Yadav, 2018). Data preparation and analysis will now be discussed further.

4.7.1. Data Preparation

Data preparation is about organizing a large amount of information for the purpose of analysis. It involves transferring the information from spoken or written form to a typed file (Creswell, 2012). That process is known as transcription (Moore & Llompart, 2017).

Creswell (2012) further says that transcription is a process of converting audiotape recordings or field notes into textual data. In this study, data preparation started with the transcribing of the audio recordings using Microsoft Word. This produced 14 Microsoft Word documents which were comprised of both teacher and learners' utterances. Gill (2000) points out that a good transcript should contain complete, unedited information pertaining to the discourse that must be analyzed as opposed to being summarized speech or talk, and due to the fine-grained analysis in this study it was necessary to capture each and every word spoken.

The next step is data reduction (Creswell, 2012). Data reduction of qualitative data is a process by which a researcher chooses or focuses on important aspects, searching for themes and patterns (Sugiyono, 2014). In this study, data reduction involved removing non-pedagogical utterances such as those related to classroom management from the transcript. Some of the utterances contained grammatical errors as per teacher utterances from the recordings. These errors were not corrected when I transcribed them - they were recorded as-is so the analysis would be a true reflection of the nature of the teachers talk. For electronic filing purposes, the pedagogical teacher utterances were coded with numbers indicating the teacher number, lesson number and utterance number. For example, the code X: 5:3 indicate teacher X lesson 5 and utterance number 3. The utterances for each teacher were saved in two different password encrypted files for the purpose of saving the data securely in accordance with the ethical clearance requirements for the research

4.7.2. Approaches to data Analysis

Data analysis is a process of organizing data and extracting insights for the emerging of themes and patterns (Kothari, 2004). Data is analyzed and interpreted to make inferences and to draw conclusions (Ashirwadam, 2010). In this study data was analyzed qualitatively (for both semantic density and lexical density) and quantitatively (for lexical density only). A mixed method approach was followed, as explained earlier. To make the process of analysis possible, analytical coding becomes an important aspect (Elliot, 2018). Elliot (2018) explains that coding is an analytical process that involves the categorization of qualitative or quantitative data in order to expedite analysis. Medelyan (2019) distinguishes between deductive coding (or concept driven coding) where the researcher has a predetermined code that are assigned to the data, and inductive coding (open coding) where thematic codes arise from the data. This study used both.

Deductive coding was used to code the science content words for the purpose of calculating the lexical density of teacher talk. The lexical density formula that I have adopted from Jawahar (2011) requires two counts - the "science content words" and "total number of words". "Science content words" is a predetermined category which required separation of science content words from non-science-content words. This required careful coding as some words appeared eligible to be in both categories at first. This necessitated a subsequent and more fine-grained level of coding as described in section

4.7.2.1. Analysis of semantic density

The coding for SD was inductive. Inductive coding is a process whereby codes are developed as a researcher analyzes the data (Saldaña, 2009). In this study, the results from the analysis related to SD were used to profile the teacher talk. In order to do that I needed to plot the shifts in SD over time. The data points that represent the respective strengths of SD are represented on a vertical axis while time is shown on the horizontal axis. The SD translation device developed during this study is shown in Table 4.1. Translation devices are tools that relate concepts to data (Maton & Doran, 2017). The teacher utterances in the translation device are coded or categorized on the basis of the degree of condensation of meaning with SD+++ being the highest level while SD-- was the lowest. Table 4.1 shows the translation device employed in this study, and informed by the translation devices of Lindstrøm (2012), Georgiou (2014), and Conana (2016).

Table 4.1: Translation device for the coding and analysis of SD.

Description of semantic density	**SD**	**Semantic density scale (points)**
Introduction of new science/previously learned concept or procedure that condenses many meanings in a word/ phrase/ symbolic representation (including graphs and formulae).	SD+++	5
Introduction or explanation (sometimes through questioning) of science concept or procedure using two or more scientific variables/ processes/ parts; a definition; graphs incuding words, formulae in words or mathematical operation in words.	SD++	4
Introduction or explanation (sometimes through questioning) of science concept or procedure through using a single distinct scientific variable/ process/ part, or use of one or more science examples.	SD+	3
Introduction or explanation (sometimes through questioning) of science concept or procedure using everyday language and drawing on two or more everyday concepts/parts and/or everyday examples.	SD-	2
Introduction or explanation (sometimes through questioning) of science concept or procedure using everyday language and drawing on a single everyday concept/part/ and/or an everyday example.	SD--	1

4. 7.2.2. Analysis of lexical density

In order to answer the second part of the research question, I calculated the lexical density of the teacher talk. Coding for lexical density analysis was deductive. According to Saldaña (2009), a researcher assigns excerpts to predetermined codes during deductive coding. In this study there are two items namely the "number of science content words" and the "total number of words" that are needed for the analysis of the lexical density of teacher talk. The following formula by Jawahar (2011) was used as a tool to analyze the lexical density of teacher talk:

$$\textbf{Lexical Density (LD)} = \frac{\text{Number of Science Content Words}}{\text{Total number of Words}} \times 100\%$$

Based on the above formula, the first step was to identify the science content words. For the purpose of this study science content words include words that are used in a scientific context and words with relevance to science meaning and those words that show a relationship between science concepts (including mathematical operations, word formulae and numbers in words). The following steps have been followed for the coding process:

1. Firstly, I made a distinction between obvious science content words (e.g. "Electron", and "voltage") and everyday words (e.g. "Something" and "yesterday"). This resulted into two major categories of obvious science content words and everyday words.
2. I have also observed that some words have science relevance and also appear to be everyday words. These words became an intermediate category because they are everyday words with relevance to science. Those words are everyday words but when they are used together with obvious science content words, they shape scientific meanings or they make definitions of science concepts clear. Categories of such words are: words that are related to a definition of a science concepts (e.g. current is "flow" of charges, positive charges *"gain"* electrons), words that exemplifies/categorizes scientific quantities (e.g. "positive/ negative" charges), words that add science meaning to a scientific process ("*transfer*" of electrons), words that form part or give meaning to a mathematical formula/operation/equation (e.g. "*rate" ,"per", "multiply"*) including

symbols; words that are used to help with the identification of categories of science concepts (“factors”, “components”), words that indicate laws in science (“*ohm’s law”*). Some numbers in words are also part of this category while others are not counted as science content words. Numbers used together with science content words, like “five” ohms, add scientific meaning and they are therefore considered to be science content words in this study. On the other hand, a number simply stated in words for example in the utterance – “*If the atom lost an electron it forms which one*?” do not add scientific meaning and were therefore considered to be everyday words.

3. The finer coding of science content words was informed by SFL sense relations of meronymy (part-whole of a relation e.g. “electrode-cell”), hyponymy (thing-type of a relation e.g “Ohm-unit”), antonymy (opposite meaning e.g “positive- and negative”) and synonymy (same meaning e.g. dry “cells –battery”). These four concepts have been briefly explained earlier, in Chapter 3.

Below, I present two examples of coded utterances. The science content words have been underlined:

Example 1

T: We have some materials that current can flow or whereby charges can flow and some materials whereby current can’t flow. Materials that allow charges to flow are for example metals and we call them good conductors of electricity.

Example 2

T: Watts is the unit of electrical power.

In the above utterances the words *‘material’* and *‘unit’* might not initially be viewed as science content word as they appear in everyday language. However, the teacher creates a clear relationship between the words ‘*metals* and *material’* and ‘*watts* and *unit*’. The linguistic sense relation known as meronomy exists between those words. Similarly, in the following utterance the words ‘fuse’, ‘earth breaker’, ‘earth wire’ and ‘insulation’ are meronyms of ‘circuits’.

Example 3

Discuss the importance of a fuse, earth breaker and earth wire in a circuit….. Electricity can be made safer by a fuse, using a fuse, earth breaker and insulation.

4.7.2.3. Using the formula to analyze the lexical density of teacher talk

The formula that was used to calculate the LD is a follows (Jawahar, 2011):

$$\textbf{Lexical Density (LD)} = \frac{\text{Number of Science Content Words}}{\text{Total number of Words}} \textbf{ x 100\%}$$

Below, I illustrate how LD has been calculated for the utterances in Examples 1 and 2. The science content words have been underlined:

T: We have some materials that current can flow or whereby charges can flow and some materials whereby current can't flow. Materials that allow charges to flow are for example metals and we call them good conductors of electricity.

$$\text{Lexical Density (LD)} = \frac{14}{38} \text{ x } 100 = 36.84\ \%$$

T: Watts is the unit of electrical power.

$$\text{Lexical Density (LD)} = \frac{4}{7} \text{ x } 100 = 57.14\ \%$$

The mean lexical density of the utterances of the 7 lessons for each teacher was then calculated.

4.8. Use of t-test

According to Hayes (2021) a t-test is a type of inferential statistic that is used to establish if there is a significant difference between the means of two groups, which may be related in certain features. The t-test questions whether the difference between the groups represents a true difference in the study or if it is possibly a meaningless random difference (Hayes, 2021). In this study, the t-test was used to determine if there were significant differences between the means of the two teachers' talk in terms of following criteria: semantic waves, semantic range and sematic flow.

4.9. Validity and Trustworthiness

Validity and trustworthiness refers to how accurately a method measures what it is intended to measure and whether the collected data is reliable or not (Middleton, 2019). Validity and trustworthiness may be improved through certain considerations (Gay et al, 2011). Guba and Lincoln (1994) identify four important criteria for increasing validity and trustworthiness: credibility, transferability, dependability and conformability. According Lichtman (2010) credibility relates to internal validity; transferability relates to external validity; dependability relates to reliability; and confirmability relates to the degree to which the findings of the study could be confirmed by others. Creswell (2012) suggest some strategies on how to increase these four criteria of validity and trustworthiness: *credibility* may be increased by prolonged engagement, persistent observation, tranquilation and member checking; *transferability* by collection of detailed descriptive data; and *dependability and confirmability* by using an audit trail.

In this study I have used mixed method research to study the phenomena of access to disciplinary discourse provided by teacher talk. According to Jick (1979) the use of mixed method research may enhance validity and trustworthiness (Tashakkori & Teddlie, 2003). In order to increase *credibility* - prior to recording the lesson I have attended two lessons for each teacher in order to acclimatize the teachers and learners to my presence. In addition, the first 2 recorded lessons (one for each teacher) out of the total 16 recorded lessons were for acclimatization purposes only. Audio recording increases reliability, reduces cost and loss of data (Tessier, 2012). The teachers were shown how to operate the recording device in order to develop trust in them. The teachers recorded the lesson themselves and I sat at the back of the class observing the lessons to avoid my visible presence around the teacher during the lesson. By doing so learners' distraction by my presence was minimized. In order to increase *transferability*, the transcript contained relevant, complete, unedited discourse for analysis. *Dependability and confirmability* were increased by two critical friends from the Master of Education programme I am enrolled in, who were willing to listen to the recordings and check the transcription. Participating teachers were also given the audio recordings and the transcripts for the purpose of "member checking". Middleton (2019) says that researcher bias might be minimized if the research participants are involved in the checking and confirming the results.

4.10. Ethical issues

According to Wilson (2013), research involving a group of people interacting with each other has an ethical dimension. "Ethics is about obvious things like acting with honestly and integrity, acting within the law and doing the right thing" (Wilson, 2013, p.91). Ethics provide us with guidelines in terms of what can be considered acceptable and unacceptable behavior (Du Plooy-Celliers et al., 2014). This research was conducted in accordance with Rhodes University research principles and ethics requirements. The ethical clearance for this research was granted by the Education Higher Degrees Committee (EHDC) at Rhodes University (Appendix H).

Participants took part in the study on a voluntary basis. I informed them about their right to withdraw from the study during any stage of the research, without prejudice. I also informed participants of what the research is about and how the findings will be used. In order to maintain the anonymity of the participants, their names were not mentioned anywhere in the reporting of the study other than the School Principal who is a gatekeeper from whom informed consent was also needed. Similarly, the names of the schools do not appear anywhere except in the permission letters that were written to the Regional Director and the School Principal. This is because I needed their permission to collect data at the schools.

In order to avoid plagiarism, I have acknowledged other's ideas via in-text citation and full references at the end of the thesis. I did not influence the research in any way to favour any expectation (for example, that the teacher with more years of teaching experience would be a better teacher than the novice teacher or vice versa). I did not influence the teachers to talk in a particular manner as this would have jeopardized the credibility of the data. Being a passive observer, I was impartial throughout the research process. I ensured that my personal thinking, views, and beliefs about the topic did not influence the findings. The collected data has been handled with sensitivity to the condition of participants being anonymous, and the data was stored in an electronic device in password encrypted folders.

4.11. Concluding remarks

In this Chapter, I have discussed the research method of the study which is a mixed method case study underpinned by the interpretive research paradigm. The study attempts to make sense of a particular situation (subjective/relativist ontology) and from a subjectivist epistemological understanding. I have also discussed the data collection and data analysis techniques which are based on the research questions guiding the study. The processes of coding the data were elaborated on in detail, covering both the relevant deductive and inductive coding approaches. The chapter also provided a discussion on the issues of validity, trustworthiness and ethics.

CHAPTER 5. RESULTS AND DISCUSSIONS

5.1. Introduction

This chapter presents data based on recordings of seven lessons presented by two science teachers (one novice and one expert). The data analysis focused on answering the research question: 'What is the nature of a novice and experienced Namibian Grade 10 Physical Science teachers' talk during electricity and magnetism lessons in terms of LCT semantic density and SFL lexical density?' The chapter is therefore divided into two main sections. The first focuses on the semantic density of the lessons of the two teachers, and the second focuses on the lexical density. The discussion foregrounds similarities and differences in the semantic density and lexical density of the experienced and novice teachers talk. The chapter begins by presenting the profiles of the two teachers.

5.2. Participant Teachers' profiles

To maintain anonymity, pseudonyms for both the teachers and their schools have been used. Table 5.1 summarizes the profiles of the two teachers in terms of qualifications and number of years of experience teaching Physical Science.

Table 5.1: Profiles of participating teachers

Teacher (pseudonym)	**Gender**	**Name of School (pseudonym)**	**Qualifications**	**Science teaching experience**
Novice	Female	Kalele Secondary School	Grade 12, B. Ed (Hons)	3 years
Experienced	Female	Kanana Secondary school	Grade 12, BETD, ACE	12 years

Table key

BETD- Basic Education Teachers Diploma (A three-year full-time teaching qualification meant for students who have completed Grade 12. The qualification equips students with both subject content and pedagogy. It is meant to train teachers for teaching Grade 1-10)

ACE- Advanced Certificate in Education (A one-year full time or two year part-time/distance education qualification for graduates who have a basic degree without a teaching component to enhance their knowledge in terms of pedagogy. It also serves as a bridging qualification to proceed to the B. Ed (Hons) for teachers who possess a BETD or another Diploma in Education. It is meant to train teachers for teaching Grade 1-12)

B. Ed (Hons) – Bachelor of Education (Honours) (A four-year teaching qualification for prospective teachers who possess a Grade 12 certificate. The qualification is meant to equip teachers with subject content and pedagogy, for teaching Grade 1-12).

5.3. LCT semantic density analysis

This section presents the result of the LCT semantic density coding, based on the translation device presented in Chapter 4 (Table 4.1), for the utterances of the novice and experienced teachers in their respective science lessons. Thereafter a summary and discussion of the overall semantic density patterns in the teachers' talk is presented.

5.3.1. Semantic density coding and profiles

The semantic density coding, narrative, and resultant semantic density profile for lesson one by each teacher is presented in detail below. While the same detailed analysis has been completed for the other six lessons, these are located in Appendix A and B for brevity within the thesis, with the overall semantic density profile being presented here. The translation device (Table 5.2) is also repeated in this section for easy referencing.

Table 5.2: Translation device for the analysis of SD.

Description of semantic density	SD	Semantic density scale (points)
Introduction of new science/previously learned concept or procedure that condenses many meanings in a word/ phrase/ symbolic representation (including graphs and formulae).	SD+++	5

Introduction or explanation (sometimes through questioning) of science concept or procedure using two or more scientific variables/ processes/ parts, a definition, graphs in words, formulae in words or mathematical operation in words.	SD++	4
Introduction or explanation (sometimes through questioning) of science concept or procedure through using a single distinct scientific variable/ process/ part, or use of one or more science examples.	SD+	3
Introduction or explanation (sometimes through questioning) of science concept or procedure using everyday language and drawing on two or more everyday concepts/parts and/or everyday examples.	SD-	2
Introduction or explanation (sometimes through questioning) of science concept or procedure using everyday language and drawing on a single everyday concept/part/ and/or an everyday example.	SD--	1

5.3.1.1. SD coding and profile of lesson one on electrical current by the novice teacher

Semantic density coding

Table 5.3 outlines the coding description and subsequent semantic density (SD) coding score for each utterance of the novice teacher in lesson one, which focused on the concept of electrical current.

Table 5.3: Coding descriptions and semantic density (SD) coding score for all utterances of lesson one on electrical current taught by the novice teacher.

Utterance section	Description of class interaction and subsequent coding choice	SD Score
1. "Good morning class. Today we shall learn about current. Who can tell us what current is?"	Teacher introduces a new concept of current, which condenses many meanings.	5
2. "Current is the flow of charge or electrons in a closed circuit. The charges or current moves from negative to positive terminal".	Teacher scientifically unpacks the concept of current by considering two variables (flow of charge and direction of movement of charges).	4
3. "For current to flow you need two things, the battery which is the source of energy and a closed circuit".	Teacher further unpacks the concept of current by naming two components (battery and a closed circuit) that are needed for current to flow.	4
4. "There are two types of currents namely alternating current also AC and direct current, also known as DC".	Teacher refers to the two types of currents (AC and DC). Each type condenses many meanings.	5
5. "Direct current flows in one direction and alternating current switches directions back and forth".	Teacher explains scientifically the difference between the two types of currents by referring to a single variable (direction of flow).	3
6. "We use the DC in our homes while AC is used where they generate electricity at power stations".	By using everyday language teacher refers to two everyday examples where the two types of currents are used.	2
7. "The instrument that is used to measure current is called an ammeter. The unit is called ampere".	Teacher scientifically unpacks current by referring to two parts (ammeter and the unit of measurement).	4
8. "One ampere of current means one coulomb of electrical charge moving past a given point in a second, in a circuit".	Teacher explains scientifically what ampere means by referring to three parts (coulomb, moving charge and points on a circuit).	4

9. "On the three benches I placed an ammeter and other circuit components. Follow the instructions on the paper and connect the ammeter correctly in a circuit".	Teacher unpacks the science concept by using two everyday language instructions for a practical experiment.	2
10. "From your connection you have observed that the ammeter is connected in series. Remember that the ammeter is used to measure the current in a circuit and that is why we must connect it with a circuit and not connecting it in parallel".	Teacher concludes scientifically from the experiment looking at three aspects (how the ammeter is connected, the purpose of the ammeter and the consequences if connected in parallel).	4
11. "If you connect it in parallel it will cause a short circuit and the ammeter will be damaged".	Teacher further explains scientifically why the ammeter should not be connected in parallel, referring to a single component (short circuit).	3
12. "We can use Ohms' Law V equals to I the current times R the resistance to calculate the current".	Teacher introduces Ohms' Law using the symbolic formula which condenses many meanings.	5
13. "If you rearrange the formula the current I is equal to voltage divided by resistance. We need the voltage and resistance to calculate the current".	Teacher derives the formula for current using a mathematical operation and using the variables of Ohm's Law.	4
14. "The two topics resistance and voltage will be done tomorrow and Friday".	Teacher refers to the next topics of 'resistance' and 'voltage', both of which condenses many meanings.	5

5.3.1.1.1. Descriptions of Semantic density of the utterances

Utterances 1-3 (down escalator)

At the start of the lesson the teacher introduces a new scientific concept of current and solicits a definition (utterance 1; Table 5.3). The concept of current condenses many meanings within Physical Sciences, resulting in a high SD score of 5. The teacher scientifically unpacks the concept by considering two variables (utterance 2, SD score of 4) and two components (utterance 3, SD score of 4). These three utterances result in a downward escalator as depicted in Figure 5.1.

Utterances 4–11 (semantic wave)

During utterance 4 the teacher introduces two new concepts, alternating current (AC) and direct current (DC; Table 5.3). Since both concepts condense many meanings, this utterance has a SD score of 5. In utterance 5 the teacher unpacks the two concepts scientifically, referring to a single variable (direction of flow), resulting in a SD score of 3. The teacher further unpacks the concept in utterance 6 by using everyday language and drawing on two everyday examples (electricity in homes and power stations), which lowers the SD score to a 2. The SD score increases again to a 4 in utterances 7 and 8 as the teacher reverts back to more scientific explanations of current, drawing on multiple components (ammeter, units of measurement, coulomb, moving charge, points on a circuit) in the process. Utterance 9 sees the teacher again further unpacking the concept by using everyday language instructions for a practical experiment, thereby weakening the SD score to a 2. Utterance 10, however, strengthens the SD to a score of 4 as the teacher concludes scientifically from the experiment looking at three aspects (purpose of ammeter, and implications of being connected in parallel or series). The SD weakens again to a score of 3 in utterance 11 when the teacher explains scientifically why an ammeter should not be connected in parallel, referring to a single component of a short circuit. The combination of utterances 4-11 result in a wave as depicted in Figure 5.1

Utterances 12-13 (down escalator)

During utterance 12, the teacher introduces Ohm's Law, using a symbolic formula which condenses many meanings in the Physical Sciences and was therefore allocated a high SD score of 5 (Table 5.3). During utterance 13 the teacher unpacks the formula by mathematically considering the three variables of the formula for Ohm's law, thereby being allocated a SD score of 4 according to the translation device. These two utterances result in a downward escalator as depicted in Figure 5.1

Utterance 14 (single reference)

The concluding utterance 14 has a SD score of 5 (Table 5.3). The teacher refers to the next topics of resistance and voltage, both of which condense many meanings.

5.3.1.1.2. Semantic density profile

The semantic density profile for lesson1, based on the SD coding scores outlined in the previous section, is depicted in Figure 5.1. Overall, most of the lesson consisted of the teacher unpacking and repacking concepts using both less condensed, everyday explanations (SD score of 2) as well as more condensed scientific explanations (SD score of 3 and 4; Figure 6). There were also two downward escalators where a single dense scientific concept (SD score of 5) was briefly unpacked (SD score of 4). At the end of the lesson the teacher also refers to the forthcoming lesson topic, which is scientifically dense and receives a SD score of 5.

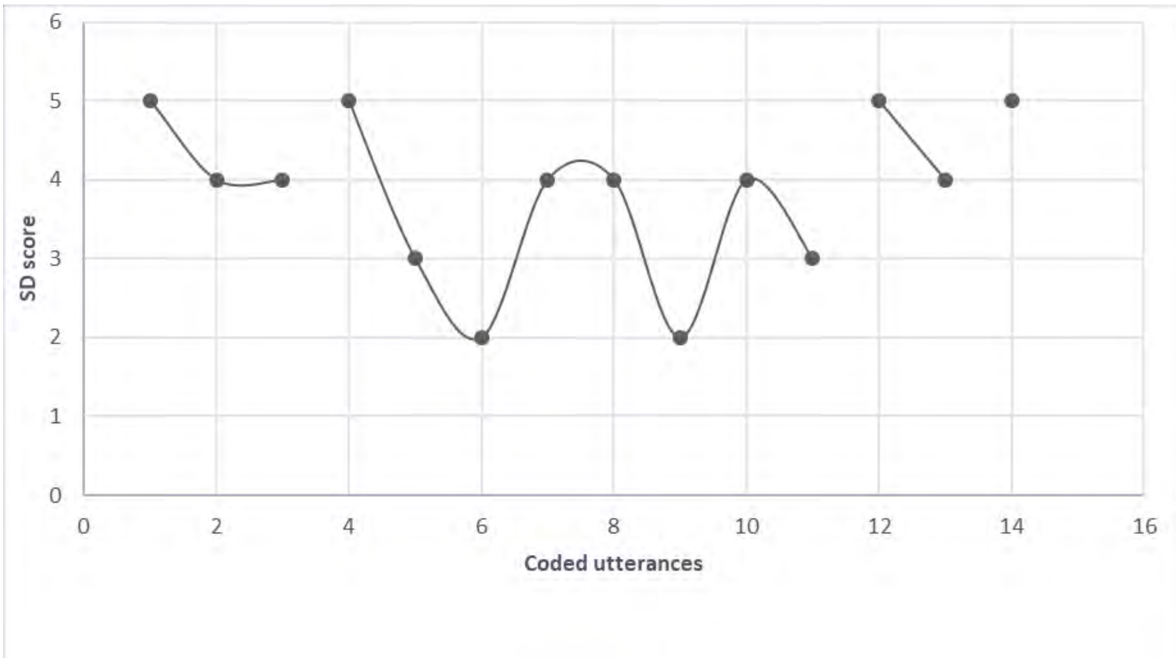

Figure 5.1: Semantic density profile for lesson one on electric current (by novice teacher)

5.3.1.2 SD profiles of lessons two to seven by novice teacher

The semantic density profile for lesson two on voltage for the novice teacher, based on SD coding scores (see Appendix A for scores and lesson narrative), is depicted in Figure 5.2. The profile is characterized by a strongly scientific approach with many utterances at a SD score of four, resulting in high flatlines. There are two downward escalators as well as some unpacking and repacking waves that remain at a relatively high semantic density (score of 3 or more). Only once in the lesson did the teacher unpack concepts using everyday language (SD score of 1 and 2). At the end of the lesson, the teacher also refers to the upcoming lesson topic of electrical resistance, which is scientifically dense and was allocated a SD score of 5

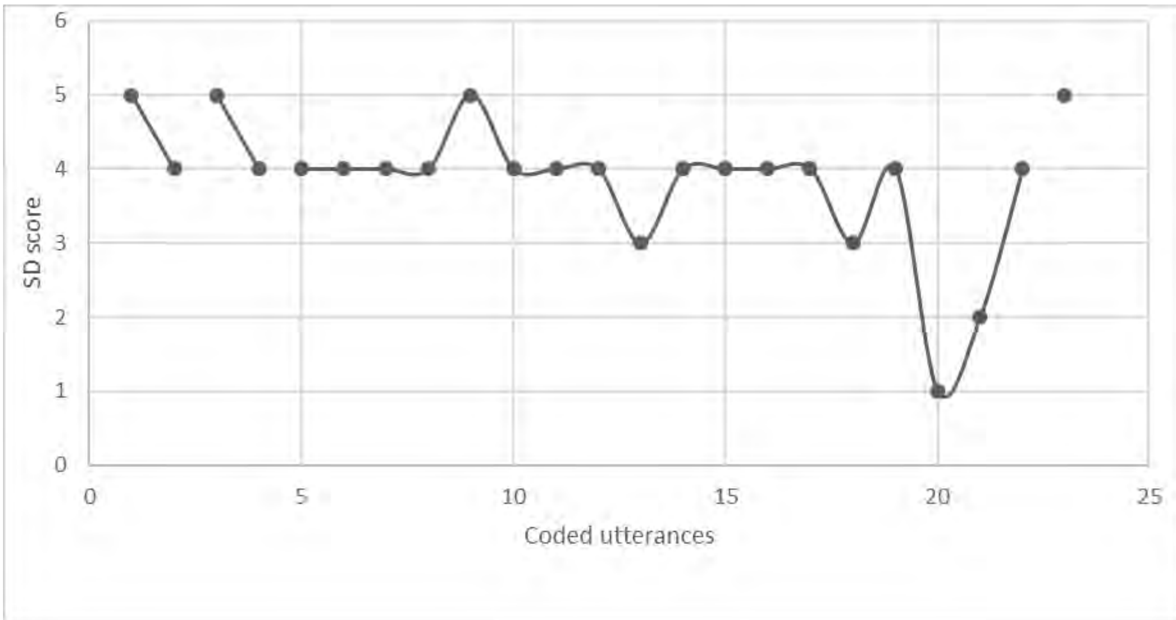

Figure 5.2: Semantic density profile for lesson two on voltage (novice teacher)

The semantic density profile for lesson three on electrical resistance for the novice teacher, based on SD coding scores (see Appendix A for scores and lesson narrative), is depicted in Figure 5.3. The profile is characterized by generally high semantic density flatlines and waves (scores of 4 and 5). The teacher draws on everyday language twice, to create semantic waves that go across the SD range. At the beginning of the lesson there is a single high semantic density downward escalator where the teacher reminds them of work from the previous lesson on voltage, and at the end of the lesson there is a single high semantic density reference to the forthcoming lesson's topic.

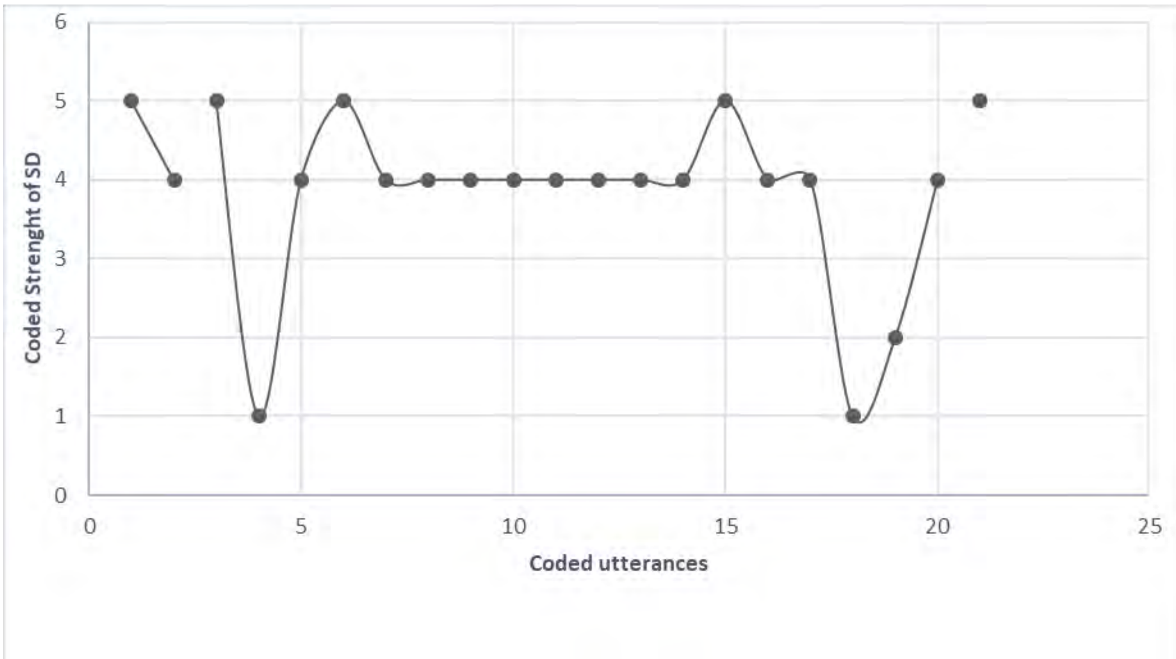

Figure 5.3: Semantic density profile for lesson three on electrical resistance (by novice teacher)

The semantic density profile for lesson four on factors that affect electrical resistance by the novice teacher, based on SD coding scores (see Appendix A for scores and lesson narrative), is depicted in Figure 5.4. The profile is dominated by high semantic density flatlines with a score of 4, with only a brief moment where the semantic density is lowered to a SD score of 2 when everyday examples are referred to. At the start of the lesson, where the teacher is referring to the previous lesson, there is a single downward escalator where a dense science concept (SD score of 5) is briefly unpacked (SD score of 4).

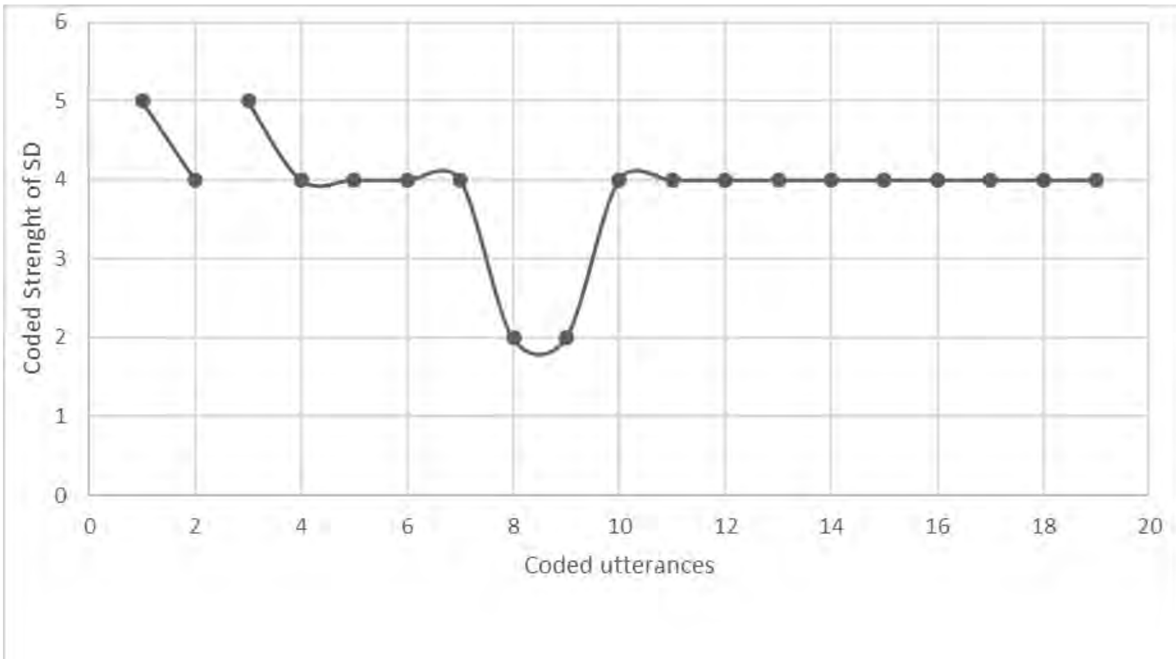

Figure 5.4: Semantic density profile for lesson four on the factors that affect electrical resistance (by novice teacher).

The semantic density profile for lesson five on electrical power for the novice teacher, based on SD coding scores (see Appendix A for scores and lesson narrative), is depicted in Figure 5.5. Overall, most of the lesson consists of the teacher unpacking and repacking dense scientific concepts (SD score of 5) using scientific explanations (SD score of 3 and 4). This results in a lesson dominated by scientific level flatlines and waves. Twice in the lesson the SD score was 1, where everyday language is used to unpack the concepts. At the start of the lesson, where the teacher is referring to the previous lesson, there is a single downward escalator where a dense concept (SD score of 5) is being briefly unpacked (SD score of 4).

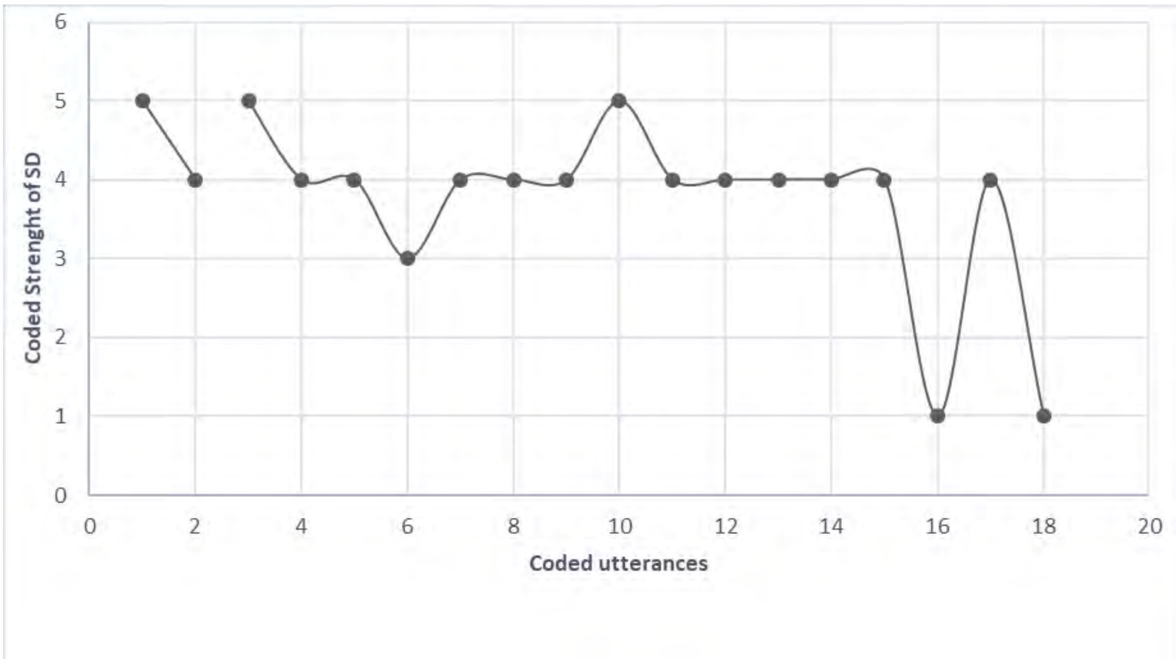

Figure 5.5: Semantic density profile for lesson five on electrical power (by novice teacher).

The semantic density profile for lesson six on uses of electricity for the novice teacher, based on SD coding scores (see Appendix A for scores and lesson narrative), is depicted in Figure 5.6. Overall, most of the lesson is dominated by low semantic density flatlines (SD score of 2). Only once in the lesson did the teacher lower the SD score to 1, and once to a score of 4. At the end of the lesson the teacher refers to the upcoming lesson topic, which is scientifically dense and receives a SD score of 5.

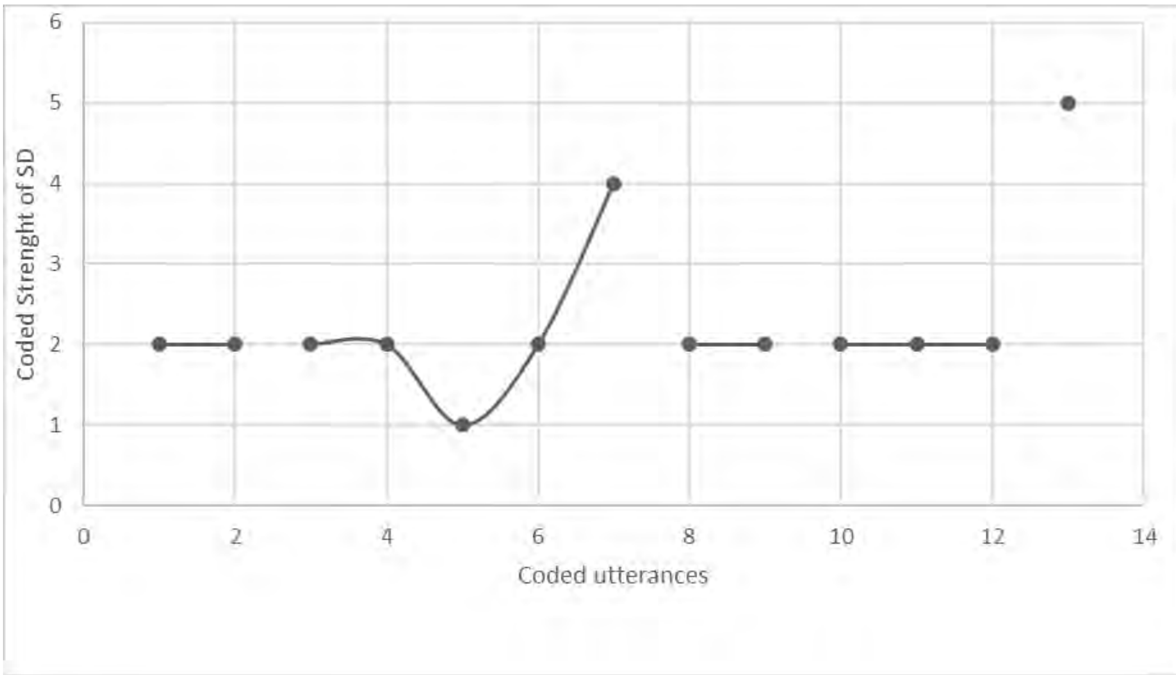

Figure 5.6: Semantic density profile for lesson six on uses of electricity (by novice teacher).

The semantic density profile for lesson seven on magnetism by the novice teacher, based on SD coding scores (see Appendix A for scores and lesson narrative), is depicted in Figure 5.7. The profile is dominated by semantic density points which are predominantly in the scientific realm (SD scores 3-5). However, the teacher does use less condensed, everyday explanations (SD score of 2) in three utterances. At the end of the lesson the teacher refers to the following lesson topic, which is scientifically dense and receives a SD score of 5.

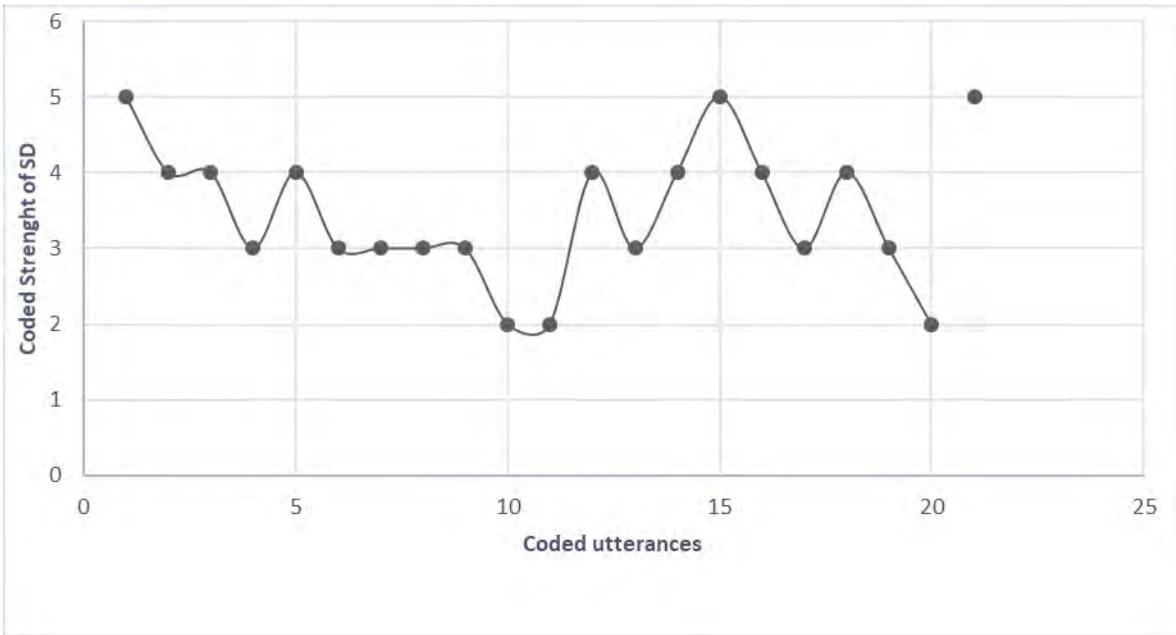

Figure 5.7: Semantic density profile for lesson seven on magnetism (by novice teacher).

5.3.1.3 SD coding and profile of lesson one on the topic of electrical current by experienced teacher

Semantic density coding

Table 5.4 outlines the coding description and subsequent semantic density (SD) coding score for each utterance of the experienced teacher in lesson one, which focuses on the concept of electrical current.

Table 5.4: Coding description and SD coding score for all utterances of lesson one on electrical current by the experienced teacher.

Utterance section	**Description of class interaction and subsequent coding choice**	**SD score**
1. "Now we can calculate the current".	Teacher introduces a science concept of current, which condense many meanings.	**5**

2. “Because we said the current is the flow of charges per unit of time so it can be calculated”.	Teacher explains scientifically what current is by considering multiple variables (flow of charges and time) and hints towards a formula.	**4**
3. “The current, the charges and the time and we calculate it using the formula as charge divided by time”.	Teacher condenses two variables, charge and time, into a word formula for current, which condenses many meanings.	**4**
4. “So, I represent the current, the charge is Q and the time is small t and this is current”.	Teacher explains scientifically the symbolic representation of the three variables (current, charge and time), of the formula.	**5**
5. “For example, we have three coulombs. The coulombs is what?”	Teacher considers a new concept (coulombs), which condenses many meanings.	**5**
6. “The coulomb is the unit of charge. Which flows”.	Teacher explains scientifically what coulomb stands for referring to two parts (unit of charges, and flow of charge).	**4**
7. “If three coulombs of charges flow through a conductor in two seconds what current will it be?”	Teacher tries to further unpack a coulomb by using an example (and hints towards a formula for current).	**3**
8. “The rule for calculation in Physical Science is first you have to write the formula right and then you identify the quantity from the scenario you are given and then you do the calculation. Here you must at least write it down. When you are calculating your writing must be going down”.	Teachers uses everyday/non-science language and generalized procedures to help explain how the calculation can be done.	**2**
9. “So you use the formula current is charges divided by time”.	Teacher reiterates the two main variables of charge and time, thus arranging it into a word formula.	**4**
10. “The charges here is three and the current that flows though the conductor in two seconds is one point five amperes”.	Teacher scientifically applies the formula for charge by referring to an example calculation.	**3**

11. “You can also calculate the charges. The formula of the current you can also derive the formula to calculate the charges. So what is the formula to calculate the charges? Charge is?”	Teacher hints via questioning towards a new formula for calculation of charge.	**4**
12. “Current times time, and time? charge divided by current”.	Teachers derives the formula for charge using a mathematical operation and using the variables of the current equation.	**4**
13. “Then the current is there in two types. There are two types of current-electron current and conventional current”.	Teacher further unpacks current by considering two types of currents (electron and conventional).	**4**
14. “The electron current is the movement of electrons in a circuit. and in electron current the electrons flow from negative to positive. That is what makes more difference. The flow of electrons from one terminal to another, which is from negative to positive. That is electron current”.	Teacher scientifically explains electron current referring to multiple variables (electron flow, positive and negative terminals of a cell).	**4**
15. “And conventional current is the agreement that current would flow from positive to negative terminal of a cell. So, this one is mainly on the direction of the electron flow”.	Teacher scientifically explains conventional current referring to multiple variables (electron flow, positive and negative terminals of a cell).	**4**
16. “We go to electrical current in circuit”.	Teacher introduces a new concept electrical current in a circuit, which condenses many meanings.	**5**
17. “So, for current to flow there must be a complete circuit. There must be complete circuit and this circuit when we say its complete it is when there is no a gap. The circuit must contain a source, the charges and the switch and bulb”.	Teacher scientifically describes a complete circuit by considering multiple parts (source, charges, switch and a bulb).	**4**

18. This circuit is not complete because the switch is open. So, there will be no current flow. the current will not reach this component the bulb.	Teacher further unpacks what an incomplete circuit is by referring to an example (comprising different parts).	**4**
19. "This circuit we call it a complete circuit because it has a closed circuit. This is a cell. if it is more than one cell it is called a battery. This is a switch. Which is a close switch. And this is a bulb. This is a conductor".	Teacher unpacks what a complete circuit is by referring to an example (comprising different parts).	**4**
20. "And the only difference between this two circuits is the open or closed switch. Here there is no current flow and here the current flows and the bulb will be hot".	Teacher compares, referring to examples, the two types of circuits (closed and open circuits).	**4**
21. "Now, we have two types of circuits- a parallel circuit and a series circuit".	Teacher introduces two types of circuits (series and parallel), both concepts condense many meanings.	**5**
22. "A parallel circuit is when the components are connected in branches, the series circuit when the components are connected one after another in one row. This one is? Parallel or series?"	Teacher explains scientifically the difference between the two types of circuits by referring to examples.	**4**
23. "This two circuits they are differ in terms of current flow, they are differing in terms of resistance and they are also differ in terms of voltage".	Teachers further explains scientifically the differences between the two types of circuits by referring to multiple variables (current, resistance and voltage).	**4**
24. "So we are going to talk about this circuits concerning the current, concerning the voltage and also the resistance".	Teacher further refers to the two circuits referring to multiple variables (current, resistance and voltage).	**4**

25. “So current first. What is the difference between current in series and current in parallel? Current in series and current in parallel. Current in series is the same at all points while current in parallel is not the same it is different”.	Teacher considers via questioning and description the difference between the two circuits (series and parallel) referring to a single variable (current).	**3**
26. “How difference it is? If the branches are having the same resistance for example here the resistance is the same then the current will divide equally”.	Teacher does a mathematical operation to differentiate between the two circuits (series and parallel) referring to two variables (resistance and current).	**4**
27. “Let me say the current here is eight and one branch will be four and in the next one also will be four”.	Teacher does a mathematical operation to further differentiate between the two circuits (series and parallel).	**4**
28. “But if the resistance is different than it will be distributed according to the resistance of each bulb. The bulb with more resistance it will have high or less current. the bulb with more resistance it will have low current or high current? Low current… and the one with low resistance it will have? high current”.	Teacher further unpacks scientifically the parallel circuits referring to multiple parts (bulb, resistance and current).	**4**
29. “They say the current entering the branch is the same as the current leaving the branch”.	Teacher does a mathematical operation to describe the current in parallel circuit.	**4**
30. “Here there is four here there is four. The total current is eight. The total current you add together the current in the branches together to get the eight. For example, if here there is three amperes and here there is five amperes to get the total you add them”.	Teacher refers to an example and does a mathematical operation to determine the total current in the circuit.	**4**

31. "And which bulb is maybe having high resistance between the two? The one with three amperes".	Teacher considers an example to describe the resistance in the circuit.	**3**
32. "Let's say you are given the total current. It is eight and you are given here there is eight amperes and you are asked to find the current in this bulb. How will you do it? You subtract the current of the one which you are given from the total current then you get the current of the bulb you were asked".	Teacher refers to an example and does a mathematical operation to determine the total current in the circuit.	**4**
33. "The current entering the branch in parallel is equal to the sum of current leaving the branch".	Teacher refers to an example and does a mathematical operation to determine and describe the total current in the parallel circuit.	**4**
34. "If the bulb or resistance are identical the current divide equally. If the resistance is not identical the current will also not be equal. The bulb with more resistance will have low current and the other one with low resistance will have more curren"t.	Teacher describes scientifically the current in a parallel circuit by referring to a relationship between two variables (current and resistance).	**4**

5.3.1.3.1. Descriptions of Semantic Density of the utterances

Utterances 1-15 (semantic wave)

At the start of this lesson the teacher introduces a new scientific concept of current, which condenses many meanings and therefore has a high SD score of a 5 (Table 5.4). Utterances 2 and 3 lower the SD score to a 4 as the teacher scientifically unpacks the concept by referring to two variables (charge and time). Utterances 4 and 5 increase the SD score from a 4 to a 5 as the teacher introduces the more dense concept of unit of charge (coulomb). In utterance 6 the teacher scientifically defines coulomb by referring to two parts (unit of charges and flow of charges), which again lowers the SD score to a 4. Utterance 7 sees the lowering of the SD score to a 3 as the teacher tries to unpack coulomb by hinting at a formula for current.

Utterance 8 further lowers the SD score to a 2 as the teacher uses everyday language and generalized procedures referring to a calculation. Utterance 9 sees the increase of SD score to a 4 as the teacher reiterates the two main variables of charge and time, condensing them into a word formula for current. In utterance 10, the SD score is lowered to 3 as the teacher uses an example to explain the formula. During utterance 11 the teacher hints via questioning towards a new formula for calculation of charge, which increases the SD score to a 4 again. Utterances 12, 13, 14 and 15 are all scored 4. During these utterances the teacher scientifically unpacks the dense concept of current through various means: using a mathematical operation to condense the two variables - current and time, into a word formula for charge (utterance 12); naming the two types of currents - electron and conventional current (utterance 13); scientifically explaining electron current by considering multiple variables - terminals of a cell and electron flow (utterance 14); scientifically explaining conventional current by considering multiple variables - terminals of a cell and electron flow (utterance 15). The combination of utterances 1-15 result in waves and flatlines as depicted in Figure 5.8

Utterances 16-34 (semantic waves)

During utterance 16 the teacher introduces a new concept of electrical current, which condenses many meanings (Table 5.4). This has a SD score of 5. Utterances 17, 18, 19 and 20 lower the SD score from a 5 to a 4. During those utterances the teacher scientifically unpacks the dense concept of electrical current through various means: referring to multiple parts of a complete circuit (utterance 17); referring to multiple parts of an incomplete circuit (utterance 18); referring to an example of a complete circuit - which comprises different parts (utterance 19); referring to examples, a closed and open circuit (utterance 20). Utterance 21 sees an increase in the SD score to 5 again as the teacher introduces the two types of circuits (parallel and series), which condense many meanings.

With utterances 22, 23 and 24 the SD score lowers to a 4 as the teacher scientifically explains by way of examples, the difference between the two circuits (utterance 22) and considers multiple variables (current, resistance and voltage) to explain the difference between the two circuits (utterance 23 and 24). Utterance 25 further lowers the SD score to a 3 as the teacher considers via questioning and description, the difference between the two circuits referring to a single variable of current. Utterance

26 increases the SD score to a 4 as the teacher does a mathematical operation while referring to two variables (resistance and current) to differentiate between series and parallel circuits.

Utterances 27, 28, 29 and 30 keep the SD score at a 4 as the teacher does a mathematical operation and refers to two variables (resistance and current) to differentiate between the two circuits (utterance 27), scientifically unpacks parallel circuits referring to multiple parts (bulb, resistance and current; utterance 28), does a mathematic operation to describe the current in a parallel circuit (utterance 29), and does a mathematical operation to determine the total current in a parallel circuit by referring to an example (utterance 30). Utterance 31 sees the lowering of the SD score to a 3 as the teacher considers an example to describe resistance in the circuits. In utterance 32 the teacher considers an example and does a mathematical operation to determine the total current in the circuit, which increases the SD score to a 4. Utterances 33 and 34 keep the SD score at a 4 as the teacher again refers to an example and does a mathematical operation to determine the total resistance in a parallel circuit (utterance 33) and by scientifically describing the relationship between current and resistance in a parallel circuit (utterance 34). The combination of utterances 16-34 result in waves and flatlines as depicted in Figure 5.8.

5.3.1.3.2. Semantic density profile

The semantic density profile for lesson one on current for the experienced teacher, based on SD coding scores, is depicted in Figure 5.8. Overall, most of the lesson consists of high density flatlines with SD score of 4. However, the teacher unpacks and repacks dense scientific concepts (SD score of 5) by using relatively condensed scientific explanations (SD score of 3 and 4), working both in semantic density flatlines and waves. Once in the lesson, the teacher lowers the semantic density to a SD score 2 when every day, non-scientific examples are referred to.

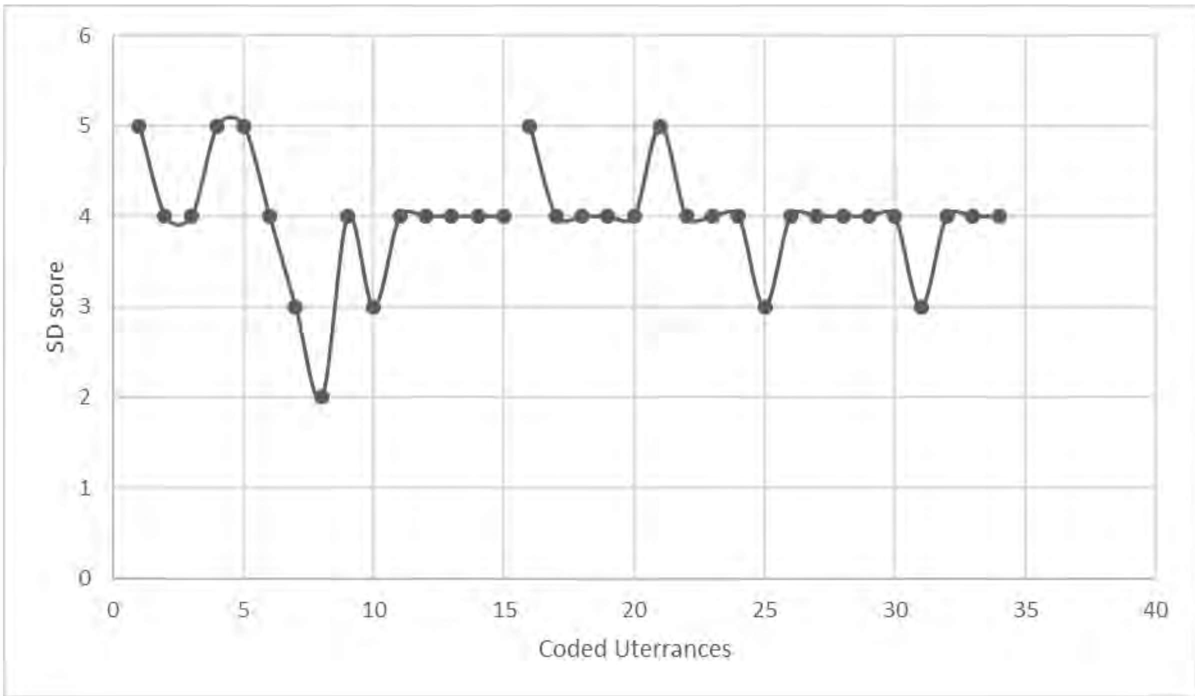

Figure 5.8: Semantic density profile for lesson one on current (by experienced teacher)

5.3.1.4 SD profiles of lessons two to seven by experienced teacher

The semantic density profile for lesson two on voltage by the experienced teacher, based on SD coding scores (see Appendix B for scores and lesson narrative), is depicted in Figure 5.9. Overall, most of the lesson consisted of the teacher producing relatively high semantic density waves through unpacking and repacking dense scientific concepts (SD score of 5) using scientific explanations (SD score of 3 and 4). Once in the lesson, the teacher lowers the SD score to 2, where everyday examples are used.

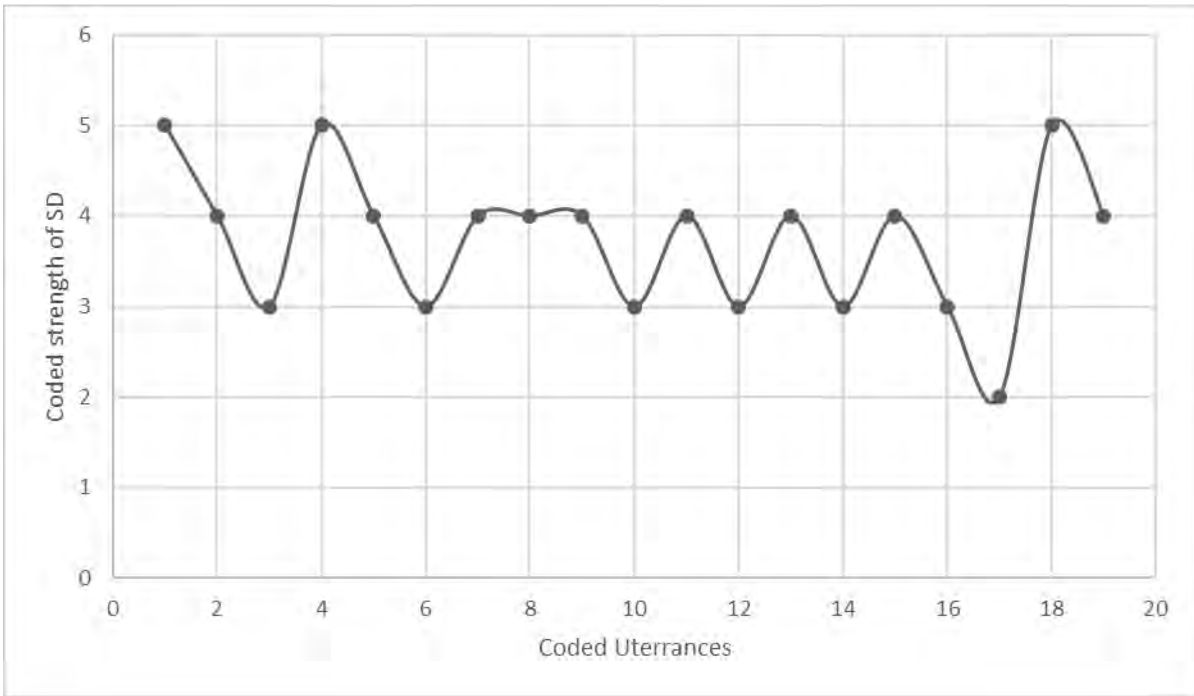

Figure 5.9: Semantic density profile for lesson two on voltage (by experienced teacher)

The semantic density profile for lesson three on electrical resistance for the experienced teacher, based on SD coding scores (see Appendix B for scores and lesson narrative), is depicted in Figure 5.10. Overall, most of the lesson consisted of the teacher unpacking and repacking dense scientific concept (SD score of 5) using relatively condensed scientific explanations (SD score of 3 and 4). This resulted in a lesson of relatively high semantic density waves and a flatline. There was one break in the wave when the teacher introduced the new high SD concept of factors affecting resistance.

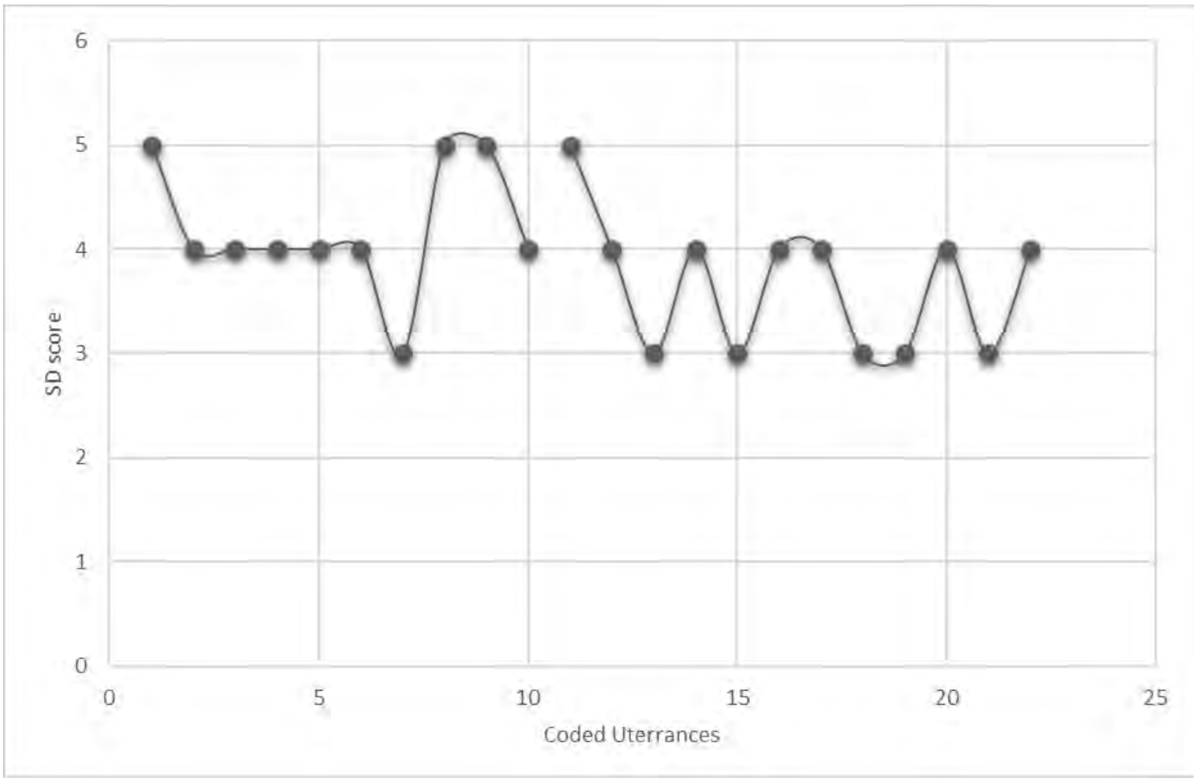

Figure 5.10: Semantic density profile for lesson three on electrical resistance (by experienced teacher)

The semantic density profile of the experienced teacher for lesson four, which was on electrical resistance (specifically related to relationship between current and voltage), is depicted in Figure 5.11. The SD coding scores and narrative that give rise to this profile are in Appendix B. The profile is characterized by a strongly scientific approach with a predominance of SD scores of 3 and above, although the teacher does draw on everyday language and examples (SD scores of 1 and 2) to explain concepts four times during the lesson. At the beginning of the lesson there is a single high semantic density downward escalator, when a teacher briefly unpacks a dense concept from the previous lesson (SD score 5 to 4). The rest of the lesson consists of SD waves, flatlines and discontinuities.

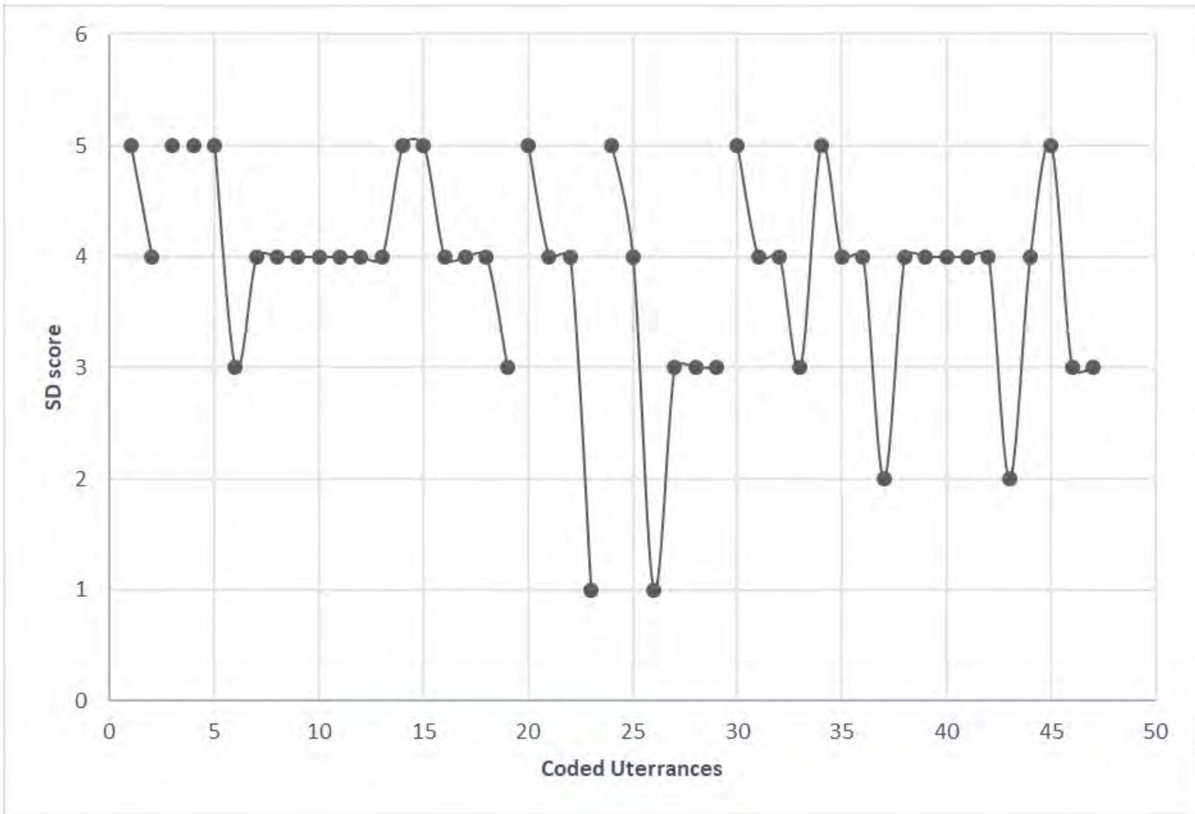

Figure 5.11: Semantic density profile for lesson four on electrical resistance (by experienced teacher)

The semantic density profile for lesson five on electrical power by the experienced teacher, based on SD coding scores (see Appendix B for scores and lesson narrative), is depicted in Figure 5.13. The profile is characterized by a strongly scientific approach with high semantic density waves (SD scores of 3 and more). There is later in the lesson, a stand-alone high semantic density reference with a SD score 5. Three times in the lesson, the teacher draws on everyday language and examples to unpack dense concepts (SD score 1 and 2).

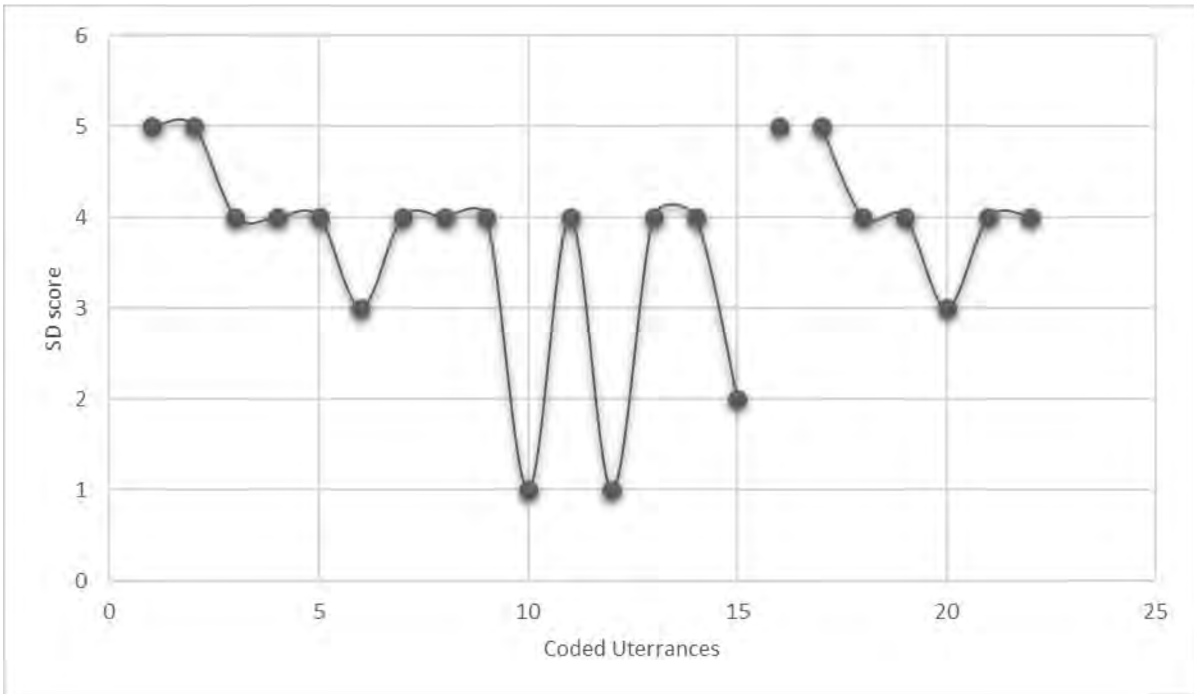

Figure 5.12: Semantic density profile for lesson five on electrical power (by experienced teacher)

The semantic density profile for lesson six on uses of electricity, by the experienced teacher based on SD coding scores (see Appendix B for scores and lesson narrative), is depicted in Figure 5.6. The stand-alone high SD utterance near the start of the lesson is when the teacher reminds learners of the previous lesson's topic. The early predominance of relatively low SD scores of 2 and 1 are linked to the topic which is everyday uses of electricity. Later in the lesson there are unpacking and repacking waves and flatlines that remain at a relatively high semantic density (SD score 3 and 4). There are also four breaks (discontinuities) in the lesson profile.

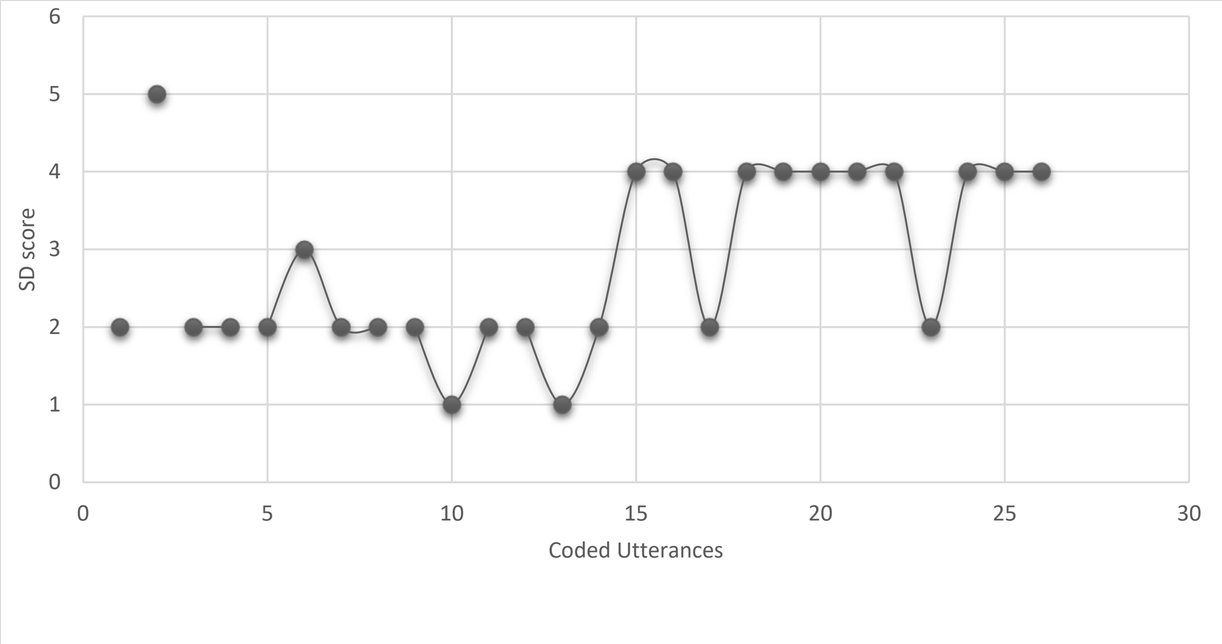

Figure 5.13: Semantic density profile for lesson six on uses of electricity (by experienced teacher)

The semantic density profile for lesson seven on electrical charge for the experienced teacher, based on SD coding scores (see Appendix B for scores and lesson narrative), is depicted in Figure 5.14. Overall, most of the lesson consisted of the teacher unpacking and repacking dense scientific concepts (SD score of 5) using both less condensed, everyday examples and explanations (SD score of 1 and 2) as well as more condensed scientific explanations (SD score of 3 and 4). Small flatlines discussing scientific concepts (SD 3 or more) are evident. There are no discontinuities in this lesson.

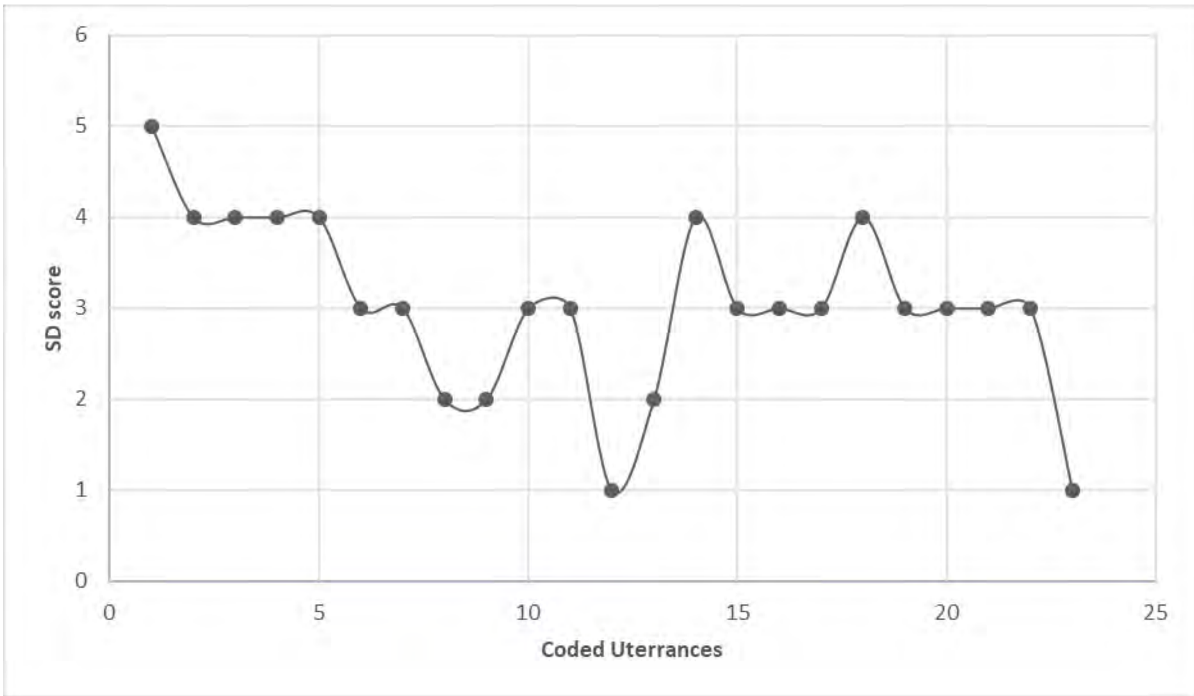

Figure 5.14: Semantic density profile for lesson seven on electrical charge (by experienced teacher)

5.3.2 Overall semantic density features of novice and experienced teachers' talk for seven lessons

5.3.2.1 Summary of semantic density profile data for the two teachers

According to Maton (2013) the different forms of semantic profiles are derived from a range of features. The three most important features in the context of this study, as discussed in the literature chapter, are semantic range, semantic waves and sematic flow. To reiterate, the larger the semantic range, the more prevalent the semantic waves, and the greater the semantic flow and connectedness of ideas, the more likely that epistemological access will be enabled (Maton, 2014) and knowledge building will take place (Maton, 2013; Maton, 2014; Clarence, 2014; Georgiou, 2014). The following summary analysis of the lesson profiles in this study is based broadly on these three features (Table 5.5). The numerical values in Table 5.5 are based on the following:

- Waves: percentage of utterances that formed part of a continuum of utterances that moved up and down the SD scale (maximum two consecutive utterances with the same SD score – thereafter it was considered a flatline).

- Flatlines: percentage of three or more consecutive utterances with the same SD score.
- Range: percentage of utterances that had a SD score of 2 or 1. In the context of this study it was felt that the use of everyday language or examples to unpack and explain dominant scientific concepts (with SD scores of 3-5) was broadening the range for epistemological access.
- Downward escalators or single references (linking): percentage of such utterances in which the teacher was providing a link to the previous or next lesson.
- Downward escalators or single references (not linking): percentage of such utterances which were isolated from previous or following ideas in the lesson.
- Discontinuities: The number of breaks in utterances during the lesson (excluding those linking previous or next lessons).

It is worth noting that the first two criteria of *waves* and *flatlines* are a measure of the general concept of semantic waves. The last three criteria *downward escalators or single references (linking)*, *downward escalators or single references (not linking),* and *discontinuities* are all part of the general concept of semantic flow. It is also worth noting that percentages for a lesson can be greater than 100% as not all categories are mutually exclusive.

Table 5.5 Semantic density profile data for the novice and experienced teachers

Teacher	Lesson	Utter-ances (n)	Semantic waves		Semantic range	Semantic flow		
			Waves (%)	Flatlines (%)	Range (%)	Linking: Down esc. or sing. refs. (%)	Breaks (n)	Non-linking: Down esc. or sing. refs. (%)
Novice	1	14	57	0	14	7	2	36
	2	23	52	48	9	13	1	9
	3	21	57	38	14	15	0	0
	4	19	32	74	11	11	0	0
	5	18	72	44	11	11	0	0
	6	13	38	70	85	8	3	0
	7	21	86	19	14	5	0	0
Mean			**56.3**	**41.9**	**22.6**	**10.0**	**0.9**	**6.4**
Experienced	1	34	65	59	3	0	1	0
	2	19	95	16	5	0	0	0
	3	22	86	23	0	0	1	0
	4	47	60	26	9	4	5	13
	5	22	86	27	14	0	2	5
	6	26	65	31	54	8	3	0
	7	23	78	48	22	0	0	0
Mean			**76.4**	**32.9**	**15.3**	**1.7**	**1.7**	**2.6**

T-tests were conducted to compare percentage values (or numbers in the case of discontinuities/breaks) for each of the six criteria in Table 5.5. In the test to compare mean percentage of semantic waving achieved by the two teachers, there was a statistically significant difference in the mean of 56.3% for the novice compared with the mean of 76.4% for the experienced teacher (t value of -2.331; p value for 2 tail test at 95% level of 0.040). The only other significant difference was for the mean values obtained for the novice (10%) and experienced (1.7%) teachers for the 'downward escalators or single references (linking)' criterion (t value of 4.649; p value for 2 tail test at 95% level of 0.001). The data from Tables 5.5 and 5.6, and its implications, are discussed in the following section.

Table 5.6: Summary of t-test values for the LCT semantic density profiles for novice and experienced teachers

t-test criteria	Semantic waves		Semantic range	Semantic flow		
	waves	flatlines	range	linking	flow	non-linking
t value	-2.331	0.784	0.579	4.649	-1.044	0.711
p value (2 tail)	0.040	0.451	0.574	0.001	0.319	0.497
significant	yes	no	no	yes	no	no

5.3.2.2 Characteristics of novice and experienced teachers talk in terms of semantic density: Implications for enabling access

Maton (2013) considers semantic density waves as a key characteristic of knowledge building and achievement. Semantic density waves tend to afford semantic access to the content and eventually enhance knowledge acquisition (Clarence, 2016; Maton, 2011). Liu (2012) also sees semantic density waving as a means of raising educational achievements as it offers a balance between the knowledge that learners are expected to learn and the knowledge they must demonstrate in any given assessment. A greater semantic range and semantic flow most likely afford epistemological access (Conana, 2016; Maton, 2013; Maton, 2014) and enable knowledge building (Clarence, 2014; Georgiou, 2014; Maton 2013; Maton, 2014). Semantic flatlines are likely to be less conducive for enabling epistemological access as they indicate that teacher fails to link previous concepts to new one (Conana, 2016).

Whilst the novice teacher made use of semantic density waves in all lessons, overall only 56% of her lessons constituted waves (Table 5.5). This was accompanied by a relatively high proportion (mean of 41.9%) of the lessons being flatlines. Whilst these two features (relatively low proportion of talk involving semantic waves, and relatively high flatlines) are less conducive for enabling access, the other aspects of the novice teacher's pedagogic practices were more conducive for such enablements. Firstly, the semantic density range was relatively large in every lesson, with at least 9% or more of all lessons drawing on everyday explanations and examples to explain scientific concepts. Secondly, non-linking down escalators and single isolated references to a particular concept were absent from five out of seven lessons. Thirdly, in terms of continuity, the total number of breaks per lesson were low, with a mean of 0.9 breaks per lesson. Fourthly, every lesson had a linking reference to either the previous lesson or the following lesson, or both (comprising a mean of 10% of the lessons) – which is in effect a form of macro semantic flow that links across the lessons.

In contrast, the experienced teacher's pedagogy exhibited a high percentage of waves in all lessons (mean of 76.4% across all lessons, as shown in Table 5.5). Whilst flatlines were also present in all lessons, the proportion was generally lower than for those of the novice teacher (mean of 32.9%). Furthermore, non-linking downward escalators and single references were only visible in two of the seven lessons. The combination of these three features indicate a relatively competent approach likely to enabling access. However, the semantic density range was relatively low in four of the seven lessons, indicating discourse that predominantly draws on the sciences for examples and explanations, without much recourse to everyday explanations, Furthermore, the number of breaks in semantic flow was greater for this teacher (1.7 breaks per lesson compared with 0.9 for the novice), and there were less linkages made between previous and following lessons (mean of 1.7% instead of 10% for the novice). These features are less conducive for enabling access.

Overall, two main trends emerge from the semantic density data for the two teachers. Firstly, the experienced teacher was (statistically) significantly better at producing semantic waves than the novice teacher. Secondly, while mostly not significantly different (except for the sematic flow macro-criterion of linking with previous and up-coming lessons) the novice teacher faired better at having a broader semantic range and greater semantic flow. These differences could possibly be ascribed to differences in their qualifications or number of years of teaching or both. Although both have shown some problems with the mastery of the content, for example when defining the concepts of current, the novice teacher managed to do better in terms of semantic range and semantic flow , possibly because her subject content is more advanced than that of the experienced teacher. The number of years of being teaching the subject could have helped the experienced teacher produce more semantic waves, affording the students better semantic access than the novice teacher.

5.4. Results related to SFL's lexical density

The data in this section relates to part (b) of the research question. In this section I present and discuss the findings for the analysis of lexical density for both experienced and novice teachers' talk. The lexical density coding selections and the resultant lexical density calculations for lesson one for the novice teacher and lesson seven for experienced teacher are presented in detail below. I randomly selected the two lessons because I want to explore and understand the pedagogic practices of the two teachers as opposed to comparing lesson to lesson or topic to topic. The same detailed coding and lexical density calculation have been completed for the other six lessons, but once again for reasons of brevity within the thesis, these are located in Appendix C and D.

5.4.1. LD results for the novice teacher

Table 5.7. Lexical density coding and calculations for lesson one on the topic of current by the novice teacher

Utterance section	Coding Notes (Coding selection)	Number of content words	Total words	LD (%)
1. "Good morning class. Today we shall learn about current. Who can tell us what current is?"	<u>Coded</u> Science concept	2	16	12.5
2. "Current is the flow of charge or electrons in a closed circuit. The charges or current moves from negative to positive terminal".	<u>Coded</u> Science concepts Word related to a science concept (categorizing science concept) Words indicating categories/types of science concepts (having antonymous relation) Words related to a science concept and shaping scientific	12	21	57.4

	process(synonymous relation)			
3. “For current to flow you need to things, the battery which is the source of energy and a closed circuit”.	**<u>Coded</u>** Science concepts Word related to a science concept (categorizing science concept) Words related to a science concept and shaping scientific process.	**6**	**19**	**31.6**
4. “There are two types of currents namely alternating current also AC and direct current, also known as DC”.	Science concepts (abbreviated and written in words) Numbers written in words categorizing science concepts) Antonymous words which are collocated with science concepts (and which indicate categories of science concepts).	**8**	**18**	**44.4**
5. “Direct current flows in one direction and alternating current switches directions back and forth”.	**<u>Coded</u>** Science concepts Words related to a science concept and shaping scientific process. Antonymous words which are collocated with science concepts (and which indicate categories of science concepts).	**5**	**14**	**35.7**

6. “We use the DC in our homes while AC is used where they generate electricity at power stations”.	Science concepts (abbreviated and written in words)	**3**	**18**	**16.7**
7. “The instrument that is used to measure current is called an Ammeter. The unit is called Ampere”.	Science concepts Units in science Words which are collocated with science concepts (having thing/type relations).	**5**	**17**	**29.4**
8. “One ampere of current means one coulomb of electrical charge moving past a given point in a second, in a circuit”.	Science concepts Numbers written in words quantifying science concepts Words shaping a scientific process.	**9**	**18**	**50.0**
9. “On the three benches I placed an Ammeter and other circuit components. Follow the instructions on the paper and connect the ammeter correctly in a circuit”.	Science concepts	**4**	**25**	**16.0**
10. “From your connection you have observed that the ammeter is connected in series. Remember that the ammeter is used to measure the current in a circuit and that is why we must connect it with a circuit and not connecting it in parallel”.	Science concepts	**7**	**41**	**17.1**
11. “If you connect it in parallel it will cause a short circuit and the ammeter will be damaged”.	Science concepts Words shaping a scientific process.	**4**	**17**	**23.5**

12. "We can use ohms' law V equals to I the current times R the resistance to calculate the current".	Science concepts (in words and abbreviated) Symbols of science variables and concepts. Mathematical operation in words./Words indicating mathematic operations Action words Action words indicating mathematical operation.	**11**	**19**	**57.9**
13. "If you rearrange the formula the current I is equal to voltage divided by resistance. We need the voltage and resistance to calculate the current".	Science concepts (in words and abbreviated)/Symbols of science variables and concepts. Mathematical operation in words. Words indicating mathematical operation.	**11**	**25**	**44.0**
14. "The two topics resistance and voltage will be done tomorrow and Friday".	Science concepts	**2**	**12**	**16.7**
Mean				**32.3**

Table 5.8 below shows the results of all utterances by the novice teacher for all seven lessons. Overall, Table 5.8 indicates a lexical density mean of 30.8% for all seven lessons. Table 5.8 and figure 5.15 show that a lowest lexical density mean of 8.5% is achieved during lesson six while the highest (39.1%). is observed during lesson 7. Lessons 1,2,3,4, 5 and 7 show lexical density means that are above the overall mean of the seven lessons. A total of 129 utterances have been observed of which the lowest lexical densities of 0% have been observed in utterance 4 (lesson three), utterances 16 and 18 (lesson five). It is worth mentioning that low lexical densities have been observed when: the teacher introduces a new topic at the start of the lesson; or when the teacher refers to a forthcoming topic for the next lesson at the end of the current lesson; or when the teacher gives instructions related to a practical activity or a

mathematical operation or calculations; and when the topic is of such a nature that it requires the use of simple everyday examples and language. The highest lexical density for the novice teacher is 85.7% (utterance 13 of lesson 7). Out of the total of 129 utterances, 40 showed high lexical densities of teacher talk (41.0% - 85.7%). That represents 31% of the total utterances (Table 5.8). The high lexical density utterances are observed when the teacher defines, categorizes or classifies science concepts, or does mathematical operations or calculations.

Table 5.8. Results of the LD of the teacher talk obtained from utterances of the seven lessons by novice teacher.

Utterance	LD Lesson 1	LD Lesson 2	LD Lesson 3	LD Lesson 4	LD Lesson 5	LD Lesson 6	LD Lesson 7
1	12.5	25.0	18.2	20.0	16.7	13.3	20.0
2	57.1	50.0	40.7	26.9	62.5	7.1	35.0
3	31.6	27.3	11.1	16.7	30.8	5.0	57.1
4	44.4	30.4	0.0	40.0	50.0	4.3	50.0
5	35.7	30.4	34.0	44.4	25.0	5.6	58.3
6	16.7	43.9	50.0	35.0	45.5	16.7	50.0
7	29.4	25.0	50.0	31.0	25.9	14.3	25.0
8	50.0	36.8	50.0	42.9	43.6	10.0	58.3
9	16.0	58.8	40.0	35.3	25.6	1.7	33.3
10	17.1	44.4	32.1	23.1	72.7	7.1	16.7
11	23.5	47.4	35.6	33.3	50.0	5.9	35.3
12	57.9	42.3	30.4	36.0	35.7	4.0	51.5
13	44.0	12.5	72.7	26.9	45.0	15.4	85.7
14	16.7	23.1	28.6	26.1	40.0		3.4
15		28.6	76.9	57.1	42.9		45.5
16		41.7	35.0	37.5	0.0		16.7
17		48.1	12.0	8.3	38.5		55.6
18		37.5	12.9	43.8	0.0		31.4
19		27.1	20.0	27.1			31.6
20		4.3	48.4				31.8
21		28.6	20.0				28.6
22		36.1					
23		16.7					
MEAN	**32.3**	**33.3**	**34.2**	**32.2**	**36.1**	**8.5**	**39.1**
OVERALL MEAN	**30.8**						

5.4.2. LD results for the experienced teacher

Table 5.9. Lexical density coding and calculations for utterances of lesson seven on charges by the experienced teacher

Utterance section	Coding Notes (Coding Selection)	Number of content words	Total words	LD (%)
1. "Good morning class today we shall learn about the charges".	**Coded** Science concept	1	10	**10.0**
2. "And we have two types of charges, what are they? We have two types of charges? Positive charges and negative charges".	**Coded** Science concept Numbers written in words adding scientific meaning (indicating categories/types) Words indicating categories/types(antonymous) sense relation)	8	21	**38.1**
3. "And how do charges form? For something to say it is charged it is when it does what? It is when it loses and gains electrons".	**Coded** Science concepts Words shaping a scientific process(antonymous sense relation) Word shaping scientific process.	5	26	**19.2**
4. "Okay then we have two types of charges, positive charge and negative charge".	**Coded** Science concept Numbers written in words adding scientific meaning (indicating categories/types). Words indicating categories/types(antonymous) sense relation)	6	13	**32.0**
5. "So, for something to form a charge it is when material have lost or it gained an electron and form the anion or? Cation the charge".	**Coded** Science concepts Words shaping a scientific process(antonymous sense relation)	8	25	**30.8**

	Words indicating categories/types(antonymous) sense relation)			
6. “If the element or atom or the material lost an electron - it forms which one? Is it positive or negative? If it loses an electron? It will form a positive charge”.	**Coded** Science concepts Words shaping a scientific process. Words indicating categories/types (thing/type sense relation) **Uncoded** Numbers in words not adding scientific meaning.	11	30	**36.7**
7. “And if it gains electrons? It forms a negative charge”.	**Coded** Science concepts Words shaping a scientific process. Words indicating categories/types	4	9	**44.4**
8. “A negative electron I mean negative charge, this charge especially on the material for example the ruler the plastic ruler or the plastic the pen pencil or the cloth when they are rubbed against each other than it will form the charge and you used to see the light when it is dark, on the sheets or the clothes. It gives something like a light”.	**Coded** Science concept Words shaping a scientific process. Words indicating categories/types **Uncoded** Words showing everyday examples such as ruler, clothes, pen, pencil, plastic	11	62	**17.7**
9. “So those ones are the proves that shows that there are charges or there are materials that are charged”.	**Coded** Science concept Words indicating categories/types Words shaping a scientific process. **Uncoded**	3	19	**15.8**

	Numbers in words not adding scientific meaning.			
10."When the charges are the same for example positive and positive or negative and negative they repel each other".	**Coded** Science concept Words shaping a scientific process. Words indicating categories/types(antonymous sense relations)	7	19	**36.8**
11. "And when they are different like negative and negative positive and positive they attract each other".	**Coded** Words indicating categories/types (hyponymous and antonymous sense relations) Words shaping a scientific process (antonymy to "repel")	6	16	**37.5**
12."Now, we have the charges are the ones that make us to have electricity".	**Coded** Science concepts **Uncoded** Numbers in words not adding scientific meaning.	2	14	**14.3**
13."We have two types of electricity. What are they? There are two types of electricity. You did this in grade nine right?"	**Coded** Science concept Number in words indicating categories/types **Uncoded** Numbers in words not adding scientific meaning.	4	22	**18.2**
14. "The two types of electricity. Static electricity and current electricity. What is the difference between this two?"	**Coded** Science concepts (with a hyponymous sense relation) Number in words indicating categories/types	7	17	**41.2**
15. "Static electricity is electricity which does not move. Which means	**Coded** Science concepts (with a hyponymous sense relation)	9	24	**37.5**

there are no flow of charges. The charges are not flowing along the conductor.	Science concept Words related to definition of a science concept and shaping scientific process Words indicating categories/types			
16. And current electricity is when the charges are moving along the conductor".	**Coded** Science concepts Words related to definition of a science concept and shaping scientific process Words indicating categories/types	5	12	**41.2**
17. "Static electricity is produced when non-conductors are rubbed together it can be continuously generated when the objects are rubbed against each other ".	**Coded** Science concept Words indicating categories/types	3	22	**13.6**
18. "And **current electricity the flow** of charges per unit of time".	**Coded** Science concept Words related to definition of a science concept and shaping scientific process Formula in in words	7	11	**63.6**
19. "And the current flows through the conductor such as metal, graphite and a solution".	**Coded** Science concept Words related to definition of a science concept and shaping scientific process Words indicating categories /types	6	13	**46.2**
20."We have some materials that current can flow or whereby charges can flow and some	**Coded** Science concept	8	20	**40.0**

materials whereby current cannot flow".	Words related to definition of a science concept and shaping scientific process Words indicating categories			
21."The materials that allow charges to flow are for example metals and we call them the good conductors of electricity".	**Coded** Science concept Words related to definition of a science concept and shaping scientific process Words indicating a thing/type (hyponymous) sense relation.	6	20	**30.0**
22. "And there are some materials that do not allow the charges to flow and they are called insulators or non-conductors of electricity".	**Coded** Science concept Words related to definition of a science concept and shaping scientific process Words indicating a thing/type (hyponymous) sense relation.	6	22	**27.3**
23. "And examples of non-conductors of electricity are the materials that do not allow electricity to flow through. They are plastic, wood, papers, etcetera".	**Coded** Science concept Words related to definition of a science concept and shaping scientific process Words indicating a thing/type (hyponymy) sense relation. **Uncoded** Everyday examples words like papers, wood and plastic	5	23	**21.7**
			Mean	**31.0**

Table 5.10 below shows the results for all utterances by the experienced teacher for all seven lessons. Overall, Table 5.10 indicates a mean lexical density of 32.5% for all seven lessons. Table 5.10 and Figure 5.16 show that the lowest mean lexical density of 17.7% is achieved during lesson seven while the highest of 38.0% is observed during lesson two. Lessons one, two, three, four, five and six have mean lexical densities that are above the overall mean (32.5%) of the seven lessons. A total of 193

utterances have been observed of which the lowest lexical density of 0% have been observed in utterance 35 (lesson four), utterances 10 and 12 (lesson six), and utterances 7 and 13 (lesson seven). This is mainly observed when: the teacher uses everyday examples and language to explain science concepts and when the teacher announces the next topic at the end of the lessons. On two occasions, the teacher has shown some lexical densities of 100% (utterance 18 of lesson 3 and utterance 29 of lesson four). This is observed when calculations or mathematical operations are discussed. Literature has shown that spoken texts have lower lexical density values when compared with written texts (Halliday, 1985; Ravelli, 1999). According to Ure (1971) spoken texts usually have a lower lexical density of 40% and below, as opposed to the written text that is 40% and above. Out of the 193 utterances, 50 have shown lexical densities of teacher talk above 40%, which constitute a 25.9 % of the total utterances (Table 5.10).

Table 5.10. Results of the LD of the teacher talk obtained from utterances of the seven lessons of the experienced teacher.

Utterance	LD Lesson 1	LD Lesson 2	LD Lesson 3	LD Lesson 4	LD Lesson 6	LD Lesson 6	LD Lesson 7
1	33.3	50.0	33.3	20.0	9.0	14.3	10.0
2	36.8	28.6	26.3	27.0	40.0	44.4	38.1
3	42.1	29.4	50.0	33.3	50.0	8.0	19.2
4	36.8	25.0	35.0	22.2	40.0	12.5	32.0
5	30.0	45.5	40.0	20.0	72.2	14.3	30.8
6	33.3	28.6	44.4	50.0	15.4	60.0	36.7
7	50.0	37.1	35.3	27.3	26.1	0.0	44.4
8	11.5	21.4	40.9	36.0	23.1	6.0	17.7
9	45.5	25.0	33.3	25.0	37.5	25.0	15.8
10	52.4	50.0	23.3	28.6	0.0	10.0	36.8
11	34.4	37.5	22.2	17.2	57.1	12.5	37.5
12	77.8	36.4	40.0	30.3	0.0	11.4	14.3
13	42.1	37.5	13.3	18.2	40.0	0.0	18.2
14	36.2	33.3	22.2	35.6	22.2	5.0	41.2
15	37.9	37.5	20.0	33.3	42.1	13.0	37.5
16	50.0	33.3	28.6	60.0	66.7	12.5	41.2
17	31.0	42.9	21.1	54.2	41.2	7.7	13.6
18	34.6	75.0	100.0	37.5	47.6	31.6	63.6
19	32.5	47.4	40.0	31.6	36.1	11.9	46.2
20	35.5		28.6	21.1	26.7	13.3	40.0
21	50.0		30.0	25.0	53.1	30.0	30.0
22	40.0		21.1	25.9	55.6	35.7	27.3
23	22.2			17.9		14.3	21.7
24	21.1			41.7		16.7	
25	38.1			35.0		20.0	
26	30.8			35.0		30.3	
27	30.4			33.3			
28	37.5			50.0			
29	43.8			100.0			
30	34.0			42.9			
31	29.4			36.7			
32	21.0			15.4			
33	52.9			58.3			
34	38.6			37.5			
35				0.0			
36				33.3			
37				20.0			
38				34.5			
39				14.3			
40				23.1			
41				27.5			
42				30.0			
43				45.5			
44				25.0			
45				60.0			
46				16.0			
47				18.8			
MEAN	**37.5**	**38.0**	**34.0**	**32.6**	**36.4**	**17.7**	**31.0**
OVERALL MEAN				**32.5**			

5.4.3. Characteristics of novice and experienced teachers talk in terms of lexical density: Implications for access

Based on the results of Figure 5.15 and Figure 5.16 and the Tables that are indicating the lexical density means (Tables 5.8 and 5.10) - both teachers have shown lower lexical densities means that are less than 40%, for the seven lessons. Lower lexical density is characterized by fewer lexical items (content words) in speech (Rahmansyah, 2012). Castello (2008) states that lexical density of written text is higher than for speech. Typical written lexical density is above 40% while typical spoken lexical density is below 40% (Castello, 2008). Although the two researchers refer to linguistics results, their conclusions seem to be applicable to other disciplines as well. A study by Jawahar and Dempster (2013) which undertook SFL analysis of the utterances of three South African Physical Science teachers, recorded a highest lexical density mean of 29.66%. However, Table 5.8 and 5.10 show that the overall lexical density of the novice teacher is slightly lower (30.86%) than that of the experienced teacher (32.37%), which is contrary to what one perhaps would have expected (that the novice teacher's lexical density would have been higher than the lexical density of the experienced teacher).

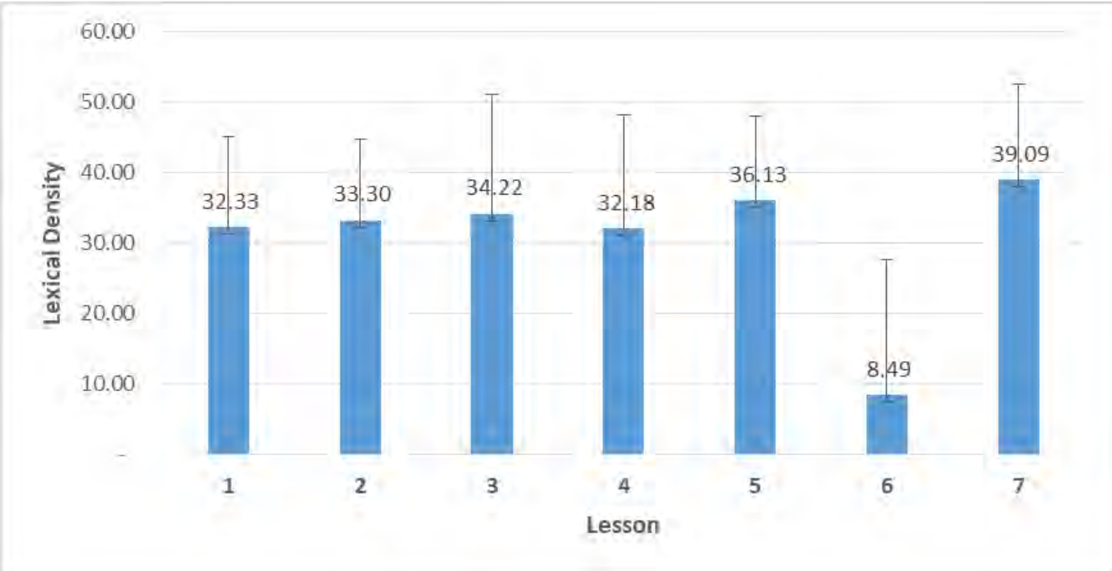

Figure 5.15. Graph showing overall mean lexical density values for the lessons by the novice teacher

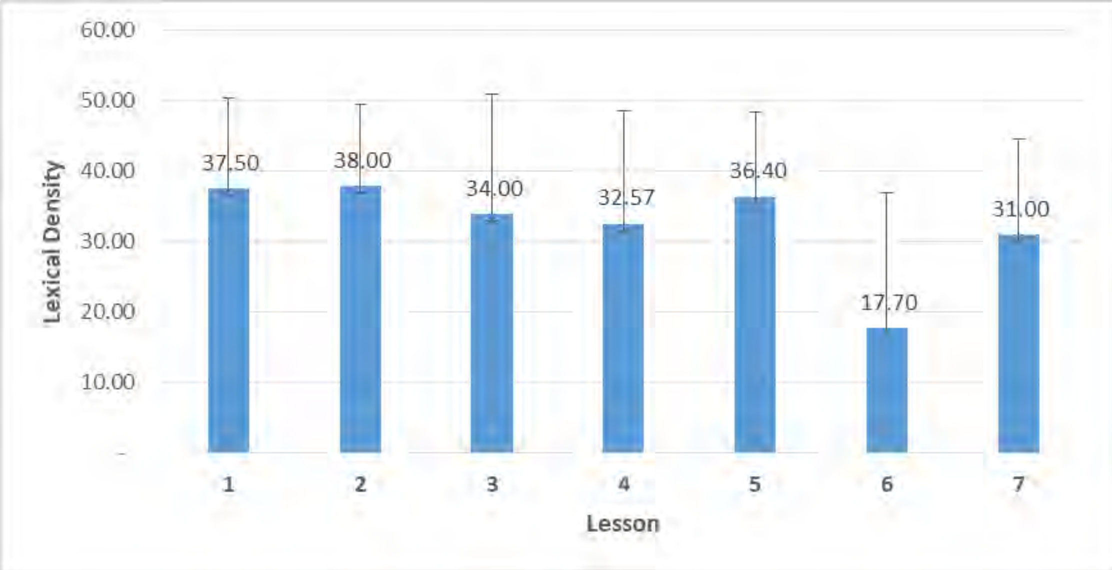

Figure 5.16 Graphs showing overall mean lexical density values for the lessons by the experienced teacher

Lexical density is considered as a measure of the complexity of language (Halliday, 1993) and it is a well-known and acceptable standard of measuring productive vocabulary (Laufer & Nation, 1995). If teacher talk has a higher lexical density, the learners will have difficulty to understand the talk and as a result they may not understand the content. Considering the overall lexical density of the teachers, one can see that both teachers afford similar lexical access to content because the lexical densities of their utterances are low (below 40%). However, the degree to which both teachers afford lexical access places doubt as to whether the learners understand the content. Except for lesson six on the uses and dangers of electricity (novice teacher) and lesson seven on charges (experienced teacher), the rest of the seven lesson's lexical density means are closer to the higher side or threshold (closer to the 40% cut off point) this may be problematic for learners to acquire epistemological access. In addition, 31% of the utterances for the novice teacher and 25.91% for the experienced teacher may be problematic in terms of affording lexical access (Table 5.8 and 5.10). The difference between their overall means for the seven lessons is 1.7 %. It is also worth noting that although their overall lexical densities are low for the seven lessons there are individual sub- subtopics showing high lexical densities (above 40%) for both teachers. The teachers crammed a lot of information in a dense manner, especially with the explanations of formulae and mathematics operations, thus posing difficulties in terms of learners understanding of content knowledge. This may affect their academic performance.

5.5. Concluding remarks

In this chapter, I have presented and discussed the results of the analysis of one novice and one experienced Physical Sciences teachers' talk from lessons on electrical current. The aims of the analysis were: firstly, to generate semantic profiles of the two teacher talk using LCT's semantic density as the analytical tool, and secondly, to calculate the lexical density of the utterances of both teachers when teaching the topic of electricity and magnetism. The findings revealed that the experienced teacher was better at semantic waving with fewer flatlines while the novice teacher talked across a broader semantic range and with better semantic flow. The results in terms of SFL's lexical density has shown little difference between the two teachers. The difference between their overall means is 1.7% (32.5 % for the experienced teacher and 30.8% for the novice teacher). Both teachers have shown lexical density levels that are below 40% which indicates that there is a likelihood that they both afforded lexical access to learners. As for semantic access, the experienced teacher afforded better results for semantic waves while the novice did so through semantic range and semantic flow.

CHAPTER 6: CONCLUSIONS AND RECOMENDATIONS

6.1 Introduction

Poor performance in science by Namibian learners is a big concern. Research in Namibia has shown that learners have a problem with meaning-making in the topic of electricity and magnetism (MoE, 2013). Freebody (2013) and Halliday (1999) state that teachers talk facilitates meaning-making and cumulative knowledge building in a content-based classroom. However, no research literature was found for the Namibian context which explored science teacher talk in terms of semantic density and lexical density. This presented a research gap which the current thesis intended to contribute towards being filled.

Literature reveals that LCT and SFL can be used in a complementary manner to analyze pedagogic practices in science classrooms (Maton, 2013). Literature has also shown that novice and experience teachers' pedagogic practices differ in terms of lexical access (Herr, 2007) and semantic access (Scott, 2008) afforded to learners. The results reported in this study are from a Namibian case study of the teacher talk of one novice teacher and one experienced teacher during lessons on electricity and magnetism. This chapter presents a summary of the findings of the study. It also presents recommendations, limitations and the conclusions.

6.2 Summary of findings

A summary of the findings is presented in relation to the research question: 'What is the nature of a novice and experienced Namibian Grade 10 Physical Science teacher's talk during electricity and magnetism lessons in terms of both LCT semantic density and SFL lexical density. The summary is therefore divided into two parts. The first part summarizes the results from the analysis employing LCT semantic density while the second part focuses on the results for SFL's lexical density.

6.2.1 Summary of semantic density results for the teachers' utterances

Semantic profiles of the two teachers have been compiled from the qualitative data of their classroom talk. The statistical analysis of the SD profiles as depicted in Tables 5.5 and 5.6 of Chapter 5 show that there is a significant difference in SD waves and flatlines, SD range and SD flow (in terms of linking, breaks and no-linking) of the two teacher's utterances. The novice teachers talk involved relatively high flatlines and relatively low amount of waving. High flatlines are indicative of pedagogic practices that are characterized by semantically dense content (Maton, 2014) whereas waving indicates the ability of the teacher to institute the required unpacking of dense semantic concepts to the level of learners' everyday experiences and everyday language use, and again repack the concepts for sophisticated content applications (Maton, 2013; Maton, 2014; Trzebiatowski, 2015; Clarence, 2016). Therefore, in terms of the SD profiles, the novice teacher talk is less conducive for enabling semantic and epistemological access (Maton, 2014).

However, the novice teacher's relatively large semantic range and semantic flow were conducive for providing semantic and epistemological access. The novice teacher simply broadens the range for epistemological access because of the use of everyday examples and language to explain semantically dense concepts and also by having fewer discontinuities between utterances that link various scientific concepts, within the same lesson or between previous lessons and the lesson of the day.

The experienced teacher's talk is characterized by fewer flatlines and higher number of waves potentially enabling better semantic and epistemological access. However, in terms of the semantic range and semantic flow, the experienced teacher's talk potentially limited semantic and epistemological access. It is evident from the statistics summarized in Tables 5.5 and 5.6 of Chapter 5 that the experienced teacher was better at semantic waving with fewer flatlines while the novice teacher talk exhibited a greater semantic range and better semantic flow.

6.2.2 Summary of lexical density results for the teachers' utterances

Literature indicates that high lexical density is a limiting factor when it comes to lexical access (Johansson, 2008) and it is thus problematic for learning (Castello, 2008). Lexical density above 40% is considered high (Ure, 1971). It is clear from the data in Tables 5.8 and 5.10 that both teachers afford lexical access to learners. This is because the overall mean values for the lexical density of their talk is below the 40% level which is typical for spoken texts (Rahmansyah, 2012). However, their overall mean lexical density values are close to 40% which indicates that the talk is veering towards the level of complexity associated with written texts.

The novice teacher's talk had an overall LD of 31.25% while the experienced teachers' talk had an overall LD of 29.91%. The LD values extending towards the complexity of written texts is in part, due to the teachers' talk including scientific terms and science formulae. Newland (1977) and Zevenbergen (2001) have indicated that language and linguistic structure of a formulae or mathematical problems present challenges to learners and therefore urge teachers to be considerate of the lexical density and semantic complexity of content presented by them.

6.3 Recommendations

The use of English, which is the language of instruction in Namibia, poses serious challenges to teachers during the delivery of subject content to learners (Wolfaardt, 2001) and Physical Science is no exception (Lubben et al., 2005). Literature suggest that lexical access and semantic access of teacher talk improve or hinder epistemological access to subject content by learners. The results of the study have very important practical contribution to Education managers (Regional Directors, School Inspectors and Advisory teachers), School Managers (School Principals and Head of departments), pre-service training and in-service professional development of Physical Science teachers. Teacher training institutions and continued professional development ought to inculcate awareness of the issue of linguistic and semantic access, and how a teacher's talk may hinder or enable these. It should not be assumed that expert teachers are more skilled at providing lexical and semantic access, compared to their more novice counterparts.

SFL and LCT are complex and broad theories that provide the appropriate tools to analyze language complexity (lexical density) and semantic complexities (semantic density) of teacher talk. Some studies have been done in Namibia which employed SFL in Namibia, such as: A functional linguistics analysis of representative Namibian poems from the spoken word by Kamanda (2019); An investigation of a Systemic Functional Linguistic approach for teaching Energy to grade 7 Natural Science and Health Education Learners by Silvanus (2017) ; and Intersemiotic Complementarity (Nakakuwa, 2019).

No Namibian study could be found prior to the commencement of the current study, which employed LCT. This thesis demonstrates the utility of LCT for profiling Namibian science teacher talk. This is especially significant in the country, considering that most learners are studying in a language (English) that is not their mother tongue, and most teachers are teaching in English even though it is not their mother tongue. It will be worth conducting a similar study on the lexical density and semantic density of teacher talk during lessons focusing on other science topics, and also on learners' talk and written work, in order to explore what it reveals about the learning process over time. Such a study could also be conducted on formative and summative assessment tasks documents and memoranda in order to determine the similarities and differences between assessment for and of, learning.

6.4 Limitations

It is recognized that results of a case study are not generalizable (Creswell, 2014). The sample of participants used in this study is small and therefore the findings can't be generalized to broader levels in Namibia and beyond. This study is limited to English second language (ESL) classrooms in the Oshana region and therefore the results can't be generalized to include EFL learners or other regions. The talk of individual teachers, have different semantic waves (Maton, 2013) and therefore the semantic profiles of the two teachers can't be generalized to all Physical Science teachers with similar years of teaching experience in Physical Science. The study considered Grade10 topics of electricity and magnetism and therefore can't be generalized to other subject, grades or other Physical Science topics. Despite the impediments to generalizability, the utility of this research is of immense importance to science education in Namibia as highlighted in section 6.3. This study had no intention to generalize the findings but to provide an understanding of access to disciplinary discourses provided by novice and experienced teachers in authentic classroom settings. It offers the opportunity to study and understand complex situations within wider social situations (Bennet & Elman, 2010).

Other limitations were that the subtopics/lesson structure were not entirely consistent across the lessons by each teacher and the modes of teaching in some cases were also not the same. There were cases where, for example, when teaching the same concept one teacher used practical activities to explain the content while the other didn't.

6.5 Concluding remarks

The study has shown that the analytical tools from LCT and SFL could be used to analyze Physical Science teachers'' classroom discourse, in terms of lexical and semantic access afforded by their talk. The SD profile results are in agreement with Maton (2014), who suggests that novice and experience teacher talk are unlikely to produce similar semantic waves. It is evident from the results that the experienced teacher potentially enables semantic and epistemological access better via semantic waving whiles potentially limiting semantic and epistemological access through semantic range and semantic flow. The novice teacher potentially enables semantic and epistemological access by having a broader semantic range and better semantic flow, which contradicts Herr's (2007) notion that a novice teacher's talk is abstract and therefore limits access to disciplinary discourse for the learners. The results also reveal that the density of teacher talk may be playing a role in Namibian learners' poor performance for the topic of electricity and magnetism.

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Appendix A : Coding description and SD coding score for all utterances of lesson two to seven for the novice teacher.

Table 2 : Coding description and SD coding score for all utterances of lesson two on voltage for the novice teacher.

Utterance section	**Description of class interaction and subsequent coding choice**	**SD Scale**
1.Class what is current? Yesterday we looked at current. What is current?	Teacher refers to a previously learned concept of current, which condenses many meanings.	**5**
2.Current is the movement of charge along a conductor in a circuit.	Teacher scientifically unpacks what current is by considering three variables/parts (moving charges, conductor and circuit).	**4**
3.Today we shall look at voltage, also known as potential difference.	Teacher refers to new concept of voltage, which condenses many meanings.	**5**
4.Voltage is electric potential difference that exist between two points in a circuit. Electrons flow is a circuit and when you consider the amount of electrons at any two points in the circuit you will discover that they are not equal. It is because of that difference that we have voltage which is also called potential difference.	Teacher scientifically unpacks the concept of voltage by considering multiple variables (flow of electrons, amount of electrons, and potential difference).	**4**
5. Also when you consider the terminals of a cell. How many terminals do we have? Name them? Positive and negative terminal, they are two.	Teacher scientifically unpacks potential difference (voltage) by referring to two parts (positive and negative terminals)	**4**
6.The terminals also have potential difference. It is that potential difference that are forcing the charges to move from negative to positive terminal. They are gaining a force to move from one terminal to another. They call that force an electromotive force.	Teacher links scientifically the two concepts of potential difference (forcing movement of charges) and electromotive force.	**4**

7.How do we measure voltage and what is the unit of voltage?	Teacher via questioning unpacks scientifically voltage by hinting towards an instrument that is used to measure it, and its unit.	
8.Voltage is measured with a voltmeter and its unit is Volt, capital V. The voltmeter is placed across the resistor.	Teacher further unpacks scientifically voltage by referring to multiple parts (instrument, unit and location).	**4**
9.To calculate the voltage across a bulb or a resistor we use the formula V equals I times R.	Teacher refers to a symbolic formula of voltage, which condenses many meanings.	**5**
10.I stand for current and R stands for resistance.	Teacher explains scientifically the symbolic representation of the two variables (current and resistance).	**4**
11.Here if the current is 3 amperes and the resistance is 2 ohms the voltage will be 6 volts.	Teacher scientifically applies the formula for voltage by referring to an example calculation.	**4**
12.Next, we look at voltage in series circuit and voltage in parallel circuit. The voltage in series and in parallel is not the same, it differs.	Teacher explains scientifically by pointing that there is difference in voltage in the two type of circuits (parallel and series).	**4**
13. If you have series circuit like this one. You can see that the components, which are the three bulbs, are connected in a straight line.	Teacher describes scientifically how bulbs are connected in parallel based on a single part (in a straight line).	**3**
14.The voltage become less as it is consumed by the components, the bulbs.	Teacher explains scientifically decrease in voltage in a series circuit by mentioning single part (consumption of voltage).	**4**
15.In this case the voltage that is supplied by the battery equals the sum of the voltage of the three bulbs.	Teacher refers to mathematical operation regarding the voltage in series.	**4**
16.If you take V1 plus V2 plus V3 it will give you the total Vt. That is the formula for the resistance in series	Teacher considers scientifically the variable (voltage) of the three components and condenses them into a word formula.	**4**

17. Here you can see that V1 is 1,5 Volts, V2 is 1.5 Volts and V3 is 2 Volts. What is the total voltage? It is 4 volts.	Teacher scientifically applies the formula by referring to an example calculation.	**4**
18.In parallel circuits the bulbs are not connected in one line. They are connected in branches.	Teacher describes scientifically how bulbs are connected in parallel based on a single part (in branches).	**3**
19. In parallel the voltage will be the same for each component. This means that the voltage in this bulb is the same as the voltage in that bulb and also the same in this one which is the same as the voltage in the cell or the battery.	With the help of the drawing/example teacher describes scientifically the voltage in a parallel circuit based on two parts (same voltage in bulbs and cells) .	**4**
20.Now, please try to do the four examples in the worksheet. Once again do not forget to indicate the units for each step.	Teacher uses everyday language referring to classwork and the inclusion of units (single variable) during calculations.	**1**
21.Your answers are correct but what is your conclusions for bulbs in series and bulbs in parallel about the total voltage?	Teacher uses everyday language to enquire about science concept (total voltage) in the two types of circuits (series and parallel).	**2**
22.The bulb in series the voltages add up to give you the total voltage of the battery while in parallel the voltage in each resistor is the same as the one in the battery or cell.	Teacher refers to a mathematical operation regarding the total voltage in series and parallel circuits.	**4**
23. Our next topic will be resistance.	Teacher refers to the next lesson on resistance, which condenses many meanings.	**5**

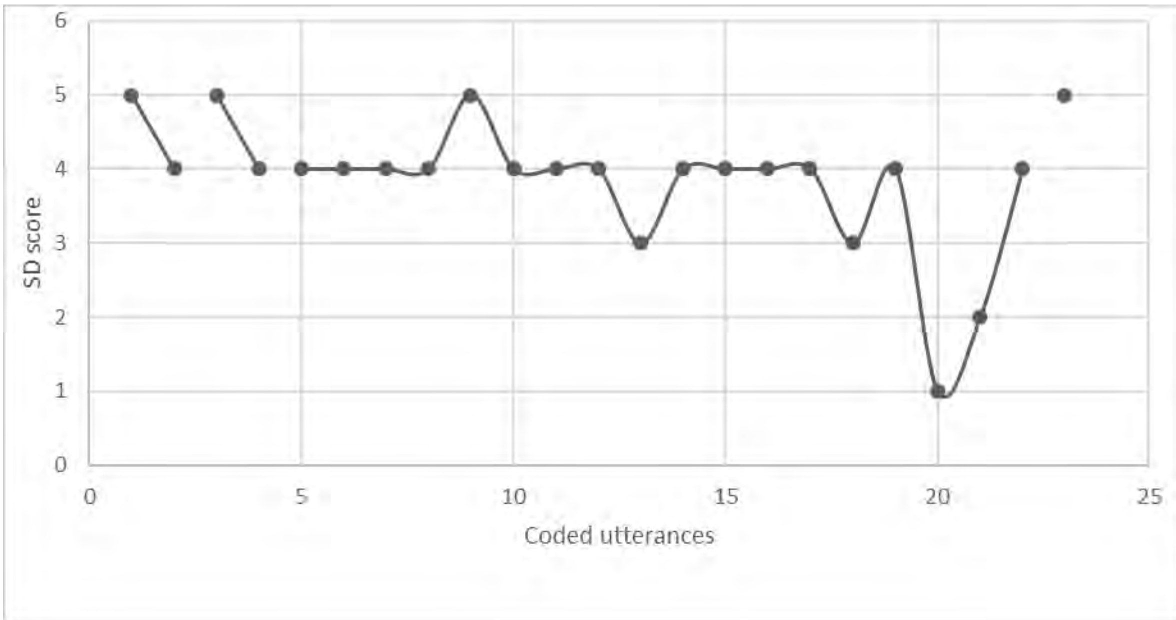


Figure 7: Semantic density profile for lesson two (Novice teacher)

Utterances 1-2 (Down escalator)

At the start of this lesson the teacher refers to a previously learned scientific concept of current (utterance 1, Table 2 and Figure 7). The concept condenses many meanings and therefore it is coded with a score of 5. The teacher scientifically unpacks the concept of current by considering three parts (utterance 2) which lowers the SD score to 4.

Utterances 3-4 (Down escalator)

With utterance 3 (Table 2 and Figure 7) the teacher introduces a new science concept of voltage. The concept condenses many meanings and it is coded with a score of 5. The teacher scientifically unpacks the concept of voltage in utterance 4 by considering multiple parts. This unpacking lowers the SD score to 4.

Utterances 5-22 (combination of semantic waves and high semantic flatlines)

Utterances 5 to 8 (Table 2 and Figure 7) are all scored 4. During those utterances the teacher continues to explain the dense concept of voltage by drawing on multiple parts (the positive and negative terminals of a cell, movement of charges, electromotive force, the voltmeter, the units of voltage and location). During utterance 9 the teacher refers to a symbolic formula of voltage, which condenses many meanings. This utterance has a score of 5. Utterances 10, 11 and 12 have a lower SD score of 4.

During those utterances the teachers scientifically explains the symbolic representations of the formula for voltage (utterance 10), applies the formula for voltage (utterance 11) and in utterance 12 points to the potential difference in the two circuits (parallel and series circuits). Utterance 13 has a lower SD score of 3. The teacher describes scientifically how the bulbs are connected in a parallel circuit referring to a single part (straight line). The SD score increases to a 4 in utterance 14 to 17 as the teacher scientifically explains the concept of voltage by considering multiple parts (voltage in series circuit, using mathematical operation and condensing symbolic variables in a word formula). The teacher unpacks the concept further in utterance 18 by referring to how a bulb is connected in a parallel circuit based on a single part (connection in branches). This decreases the SD score to 3. In utterance 19 the teacher reverts back to describing scientifically the concept by referring to multiple parts (same voltage in bulbs and cells) in a parallel circuit. Therefore, the SD score in utterance 19 increases to a 4. With utterance 20 the teacher lowers the SD score to a lowest level in this lesson of 1 by using everyday language about classwork procedure and reminds learners about one aspect of their calculations (to not forget to write units). During utterance 21 the teacher also uses everyday language but refers to two aspects they need to consider (bulbs in series and parallel) which increases the SD score to a 2. Utterance 22 further increases the SD score to 4 as the teacher refers to a mathematical operation regarding the calculation of total voltage in series and parallel circuits.

Utterance 23 (single reference)

Utterance 23 has a score of 5. The teacher refers to the next lesson of resistance which condenses many meanings.

Analysis of novice teacher's profile for lesson three

Table 3 below shows the coding description and subsequent SD coding score for each novice teacher utterance of lesson three on the concept of resistance. Figure 8 depicts the semantic profile for the lesson which is based on the SD coding scores. The profile is characterized by generally high semantic density waves and flatlines (scores of 4 and 5). Twice the teacher draws on everyday language to create semantic waves that go across the SD range. At the beginning of the lesson there is a single high semantic density down escalator, and at the end of the lesson a single high semantic density reference to the following lesson's topic.

Table 3: Coding description and SD coding score for all utterances of lesson three on electrical resistance for the novice teacher.

Utterance section	Description of class interaction and subsequent coding choice	SD Scale
1. Yesterday we talked about voltage. Do you remember what voltage is?	Teacher refers to a previously learned concept of voltage, which condenses many meanings.	**5**
2. We said that voltage is the electric potential difference that exist between two points in a circuit. What is the unit of voltage? The unit is volts.	Teacher scientifically unpacks what voltage is by considering two variables (definition and unit).	**4**
3. Today we shall talk about resistance. We have roughly mentioned resistance before? Can anyone recall what it is?	Teacher refers via questioning to new concept of resistance. which condenses many meanings.	**5**
4. When we say you resist to move, what does that mean? Yes, it means refuse to move.	Teacher uses everyday language to explain a science concept.	**1**
5. Resistance in Physical Science means opposition to flow of charge or current. Resistance is represented by a capital letter R and it is measured in ohms. The unit for resistance is ohms. Like current and voltage, we also use a formula to calculate the resistance. Anyone who can give us the formula?	Teacher scientifically unpacks the concept of resistance by considering multiple variables (definition, symbolic representation, units and formula).	**4**
6. The formula is R equals to V divided by I.	Teacher refers to a symbolic formula for calculating resistance, which condenses many meaning.	**5**
7.V stands for voltage and I for current.	Teacher unpacks scientifically the two variables of resistance.	**4**

8.For example, in this circuit the voltage is seven volts and the current is two amperes. The resistance will be R equals to seven volts divided by two amperes. The answer will be three point five volts, I mean ohms.	Teacher scientifically applies the formula by referring to an example calculation.	**4**
9. The total Resistance differ between a parallel and series circuit. The procedure to get the total resistance in series circuit is different from the parallel one.	Teacher explains scientifically by pointing that there is a difference in resistance in the two type of circuits.	**4**
10. Let's look at resistance in series. Here you are given the total current in the circuit and the voltage in the circuit? What will be the total resistance?	Teacher refers to a science example to unpack the concept of total resistance in series by considering two variables (current and voltage).	**4**
11. The voltage here is 6V and the total current is 3A. The total resistance will be R_T equals to 6 volt divided by 3 amperes and the answer is 2 ohms. And do not forget to write the units as you proceed doing the calculations.	Teacher scientifically applies the formula for series circuits by referring to example calculation.	**4**
12. If you have three resistors to get the total resistance you add the individual resistance. The total resistance here will be how much?	Teacher refers to mathematical operation regarding total resistance in series.	**4**
13. The total is R1 plus R2 plus R3 which is 2 ohms + 3 ohms+ 1 ohm which is 6 ohms.	Teacher refers to mathematical operation regarding total resistance in series and does a calculation.	**4**
14. Let's now look at the parallel circuit.	Teacher indicates that they will unpack scientifically the concept of total resistance.	**4**
15.The total resistance in this parallel circuit will be one over R T equals to one over R1 plus, one over R2 plus one over R1 plus, ($1/R_T$ = 1/R1+1/R2+1/R3).	Teacher considers a formula for the total resistance in a parallel circuit, which condenses many meanings.	**5**

16. This will be $1/R_T$ equals ¼ + ¼+ ½ and if we change them into decimals they will become 1/ Rt= 0.25 ohms + 0.25 ohms + 0.5 ohms which is 1/Rt = 1 ohms. To remove the one on the left side you write Rt = 1/1 . the answer will be 1 ohms.	Teacher applies the formula for resistance in parallel by using a science example and performing the calculation.	**4**
17. Therefore, in parallel circuits the total resistance will be always be smaller than any of the resistance in the branches.	Teacher refers to a mathematical operation regarding total resistance in parallel.	**4**
18. Can you do the rest of the calculations for resistance exercise and like I said. Do not forget to indicate the units when you do the calculations all the time.	Teacher uses everyday language and procedure regarding classwork.	**1**
19. Now that we have done the calculations what do you conclude about the resistance in the two types of circuits?	Teacher uses everyday language drawing on multiple concepts (resistance in series and resistance in circuit).	**2**
20. The total resistance in series circuit equals the sum of individual resistance in the resistors while in parallel circuit the total resistance is in not equal to the sum of resistors-.	Teacher explains scientifically the difference regarding the total resistance in the two types of circuits.	**4**
21. Tomorrow we shall talk about different factors that affect resistance.	Teacher refers to the next lesson on 'factors that affect resistance', which condenses many meanings. .	**5**

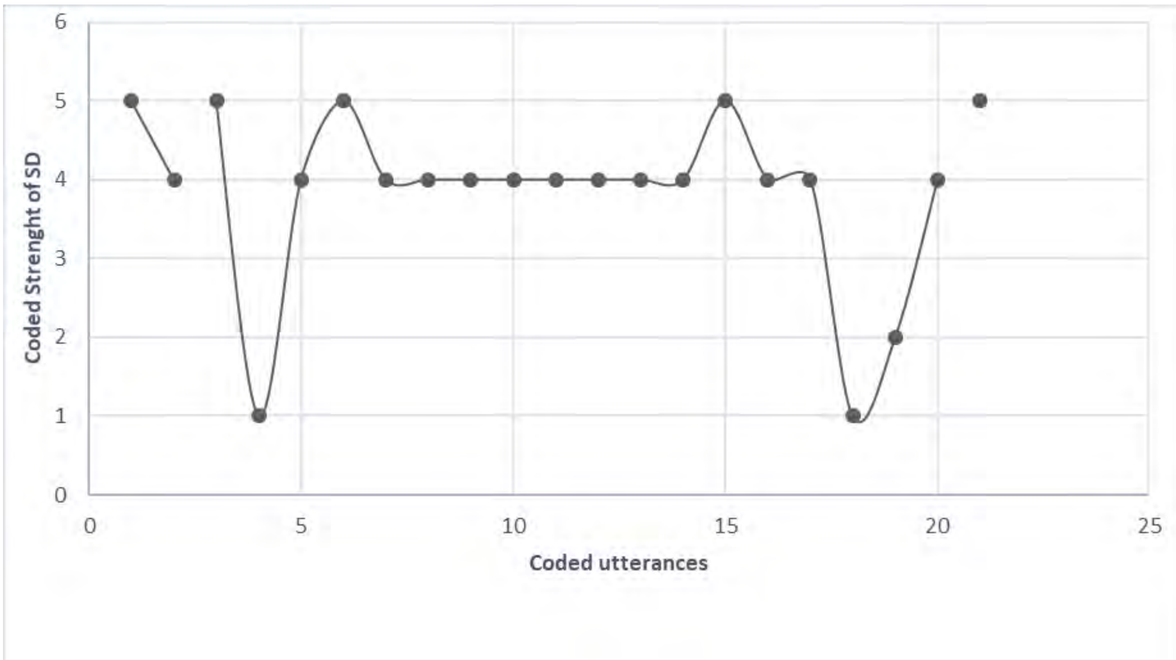


Figure 8: Semantic density profile for lesson three (Novice teacher)

Utterances 1-2 (Down escalator)

At the start of this lesson the teacher refers to a previously learned scientific concept of voltage and solicits a definition. (figure 8). The concept condenses many meanings and therefore it has a SD code of 5. The teacher scientifically unpacks the concept of voltage by considering both a definition and the units used to measure voltage, (utterance 2, figure 8), which lowers the SD score to 4.

Utterances 3-20 (semantic waves and high semantic density flatlines)

During utterance 3 the teacher introduces a new science concept of resistance which condenses many meanings, hence is has a SD score of 5 (Table 1 and Figure 8). When the teacher uses everyday language to unpack the science concept of resistance this lowers the SD score to a 1 (utterance 4, Figure 8). During utterance 5 the teacher further explains the concept of resistance scientifically by considering multiple variables (definition, symbolic representation, units and formula) increasing the SD score to a 4. Utterance 6 increases the SD score to a 5 as the teacher refers to a symbolic formula for calculating resistance. The utterance condenses many meanings. Utterance 7 decreases the SD score to a 4 as the teacher unpacks scientifically the two variables of resistance (voltage and current). Utterances 8 -13 keep the SD score at 4. The teacher scientifically unpacks the concept of resistance by a number of means: applying the formula for resistance (utterance 8), referring to the difference in resistance in the in parallel and series circuits (utterance 9), referring to two variables of current and voltage in a series circuit (utterance 10), applying the formula for resistance in series circuit (utterance 11), using a mathematical operation for the total resistance in series (utterance 12-13), and scientifically unpacking the concept of total resistance (utterance 14). The SD scores increases again to a 5 during utterance 15 as the teacher considers a formula for total resistance in a parallel circuit, which condenses many meanings. Utterances 16 and 17 decrease the SD score to a 4 as the teacher applies the formula and then does a mathematical operation for total resistance in parallel. Utterance 18 sees the lowering of the SD score to a 1 when the teacher uses everyday language and procedure regarding classwork. During utterance 19 the SD strengthen slightly to a 2 when the teacher uses everyday language considering multiple concepts by referring to the resistance in series and parallel circuits. During utterance 20 the teacher explains scientifically the total difference in resistance between the two, which further increases the SD score to a 4.

Utterance 21 (single reference)

In utterance 21 the teacher refers to the next lesson based on factors that affect the resistance, which condenses many meanings and therefore has a SD score of 5.

Analysis of novice teacher's profile for lesson four

Table 4 outlines the coding description and subsequent SD coding score for each novice teacher utterance of lesson four on factors that affect resistance. Figure 9 depicts the semantic profile for the lesson which is based on the SD coding scores. The profile is dominated by high semantic density flatlines with a score of 4, with only a brief moment where the semantic density is lowered to a SD score of 2 when everyday examples are referred to. The start of the lesson, where the teacher is referring to the previous lesson, there is a single down escalator where a dense science concept (SD score of 5) is briefly unpacked (SD score of 4).

Table 4 : Coding description and SD coding score for all utterances of lesson Four on electrical resistance for the novice teacher.

Utterance section	Description of class interaction and subsequent coding choice	SD Scale
1. Yesterday we talked about resistance.	Teacher refers to a previously learned concept of resistance, which condenses many meanings.	**5**
2. We said resistance is the opposition of flow of charge in a circuit. We also said that resistance in parallel is different from the one in series.	Teacher scientifically unpacks what resistance is by considering two parts (definition and resistance in the two types of circuits).	**4**
3. Now, we are going to talk about different factors that affect resistance.	Teacher introduces the new concept of factors that affect resistance, which condenses many meanings.	**5**
4. We have five such factors. They are four namely, temperature, the type of material, the length of the wire and the diameter of the wire.	Teacher considers scientifically the multiple factors that affect resistance.	**4**
5. Increase in temperature increases resistance. Why is it so?	Teacher consider the first factor (temperature) and describes scientifically the relationship between the two variables (temperature and resistance).	**4**
6. Because heat in the wire causes the atoms to collide with electrons and therefore the movement of electrons is limited.	Teacher explains scientifically why heat increases resistance by referring to two aspects (collision of atoms with electrons, movement of electrons being limited).	**4**
7.When it comes to the type of material some material allows electrons to move freely while some material will not. Those material that allow free movement of electrons have less resistance and they are called good conductors of electricity. Those that makes electron move difficult in them are having high resistance. They are not good conductors of electricity.	Teacher considers the second factor (type of material) and scientifically describes and explains the relationship between type of material and multiple components (movement of electrons, resistance, conductors of electricity).	**4**
8. Examples of good conductors of electricity are copper and silver. The electrons move freely.	Teacher refers to two everyday examples of good conductors of electricity.	**2**
9. And Examples of none-conductors of electricity will be glass and plastics. Electrons do not flow through them	Teacher refers to two everyday examples of non- conductors of electricity.	**2**

10. Let's look at the length of the wire. How does it affect resistance?	Teacher considers another scientific factor, length of wire, which affects resistance.	**4**
11. If the wire is longer the more resistance is more also in the wire. Why is it so?	Teacher scientifically describes the relationship between the two variables (length of wire and resistance).	**4**
12. Because if the wire is longer the electrons are traveling a longer distance as a result more collisions will take place and will the resistance be high.	Teachers scientifically unpacks the relationship between the two variables (length of a conductor and resistance) by referring to movement of electrons, a process.	**4**
13. What do you think about the diameter or the width of the wire? If the diameter is bigger the resistance will decrease? Why is it so?	Teacher considers the next factor (width of a wire) and scientifically describes the relationship between the two variables (width of a wire and resistance).	**4**
14. Because the space through which the electrons move is big. There is space to move freely with less collision. Therefore, resistance is low.	Teacher scientifically unpacks the relationship between the diameter of the conductor and resistance referring to the movement of electrons.	**4**
15. What is direct proportionality and indirect proportionality?	Teacher refers to mathematical operation to unpack the relationship between variables.	**4**
16. If for example the temperature in the resistance increases the resistance will also increase. This means that temperature is directly proportional to the resistance.	Teacher scientifically unpacks the concept of direct proportionality by referring to two variables (temperature of a conductor and resistance).	**4**
17. You can see from this graph that the line is straight up.	Teacher refers to an example (graph) to explain the relationship between the two variables(temperature and resistance) to explain a science concept.	**4**
18. And if the diameter of the conductor decrease the resistance will increase. This is indirectly proportional.	Teacher scientifically unpacks the concept indirect proportionality by referring to two variables (diameter of a conductor and resistance).	**4**

19. You can see that that graph is curving here.	Teacher refers to an example (graph) to explain the relationship between the two variables(diameter and resistance) to explain a science concept.	**4**

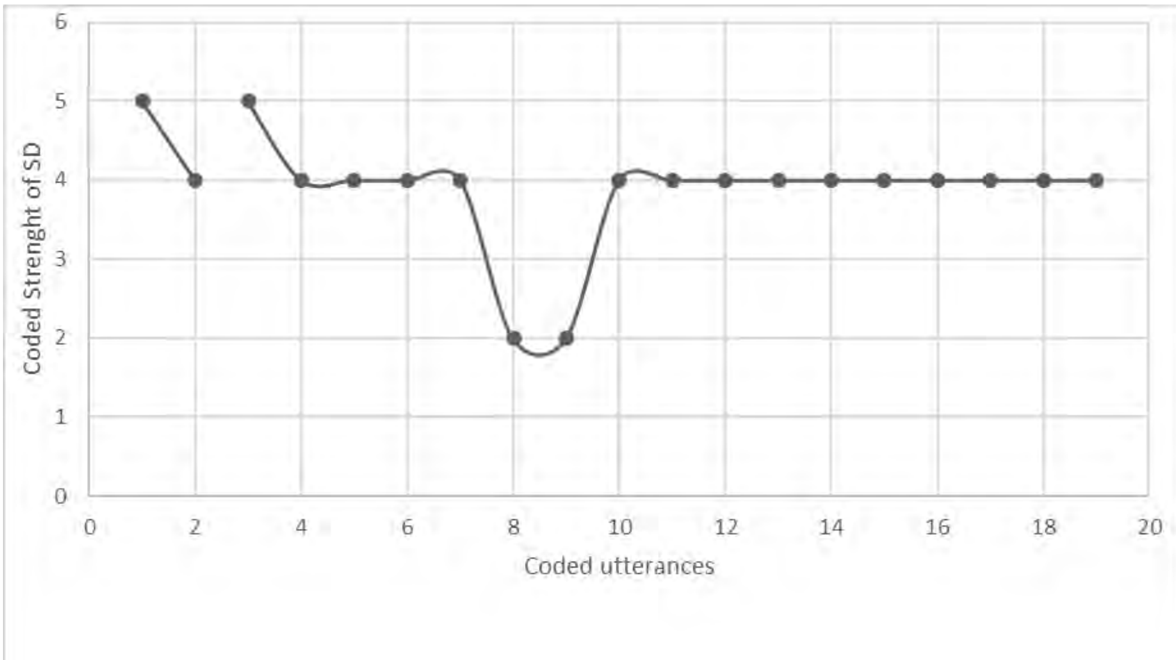


Figure 9: Semantic density profile for lesson four (Novice teacher).

Utterances 1-2 (Down escalator/downward semantic shift)

At the start of this lesson the teacher refers to a previously learned scientific concept of resistance. (figure 9), which condenses many meanings and therefore has a SD score of 5 (figure 9). The teacher scientifically unpacks the concept of resistance by considering two components: a definition and two types of circuits (utterance 2, figure 9) which lowers the SD score to 4.

Utterances 3-19 (combination of down escalator, semantic wave and high semantic flatlines)

During utterance 3 (figure 9) the teacher introduces a new science concept of factors that affect resistance which condenses many meanings, this utterance has a SD code of a 5. The teacher then scientifically unpacks the dense science concept by considering multiple factors that affect resistance, thus lowering the SD score to 4 (utterance 4, Figure 9). During utterance 5 the teacher further explains the concept by considering the first factor of temperature and by referring to two variables (relationship between temperature and resistance), which has a SD score of 4. The SD score for utterance 6 remains at 4 as the teacher scientifically explains the relationship between heat and resistance. During utterance 7 the SD score of 4 is maintained as the teacher describes and explains the second factor of type of material by considering multiple variables. At this point in the lesson the lowest level of SD score 2 is reached when the teacher refers to everyday examples of good conductors (utterance 8) and non-conductors (utterance 9) of electricity. Utterance 10 sees an increase of SD score to a 4 again as the teacher introduces another factor, the length of the wire, which affects the resistance. Utterances 11 -19 (figure 9) keep the SD score at a 4. During utterance 11-19 the teacher further scientifically unpacks the concept by the following means: describing the relationship between two variables (length of the wire and resistance; utterance 11), explaining using multiple variables referring to the length of a wire and resistance (utterance 12), introducing the next factor (width of wire; utterance 13), referring to the relationship between the two variables (width of wire and resistance; utterance 14), using mathematical operation (called direct proportionality) with regards to the relationship between the two variables (width of the wire and resistance; utterance 15), unpacking the concept direct proportionality referring to two variables)temperature of a conductor and resistance; utterance 16) , using a graphic example referring to the relationship between temperature and resistance of a conductor (utterance 17), using a graphic example referring to the relationship between diameter of a conductor and resistance (utterances 18-19).

Analysis of novice teacher's profile for lesson five

Table 5 outlines the coding description and subsequent SD coding score for each novice teacher utterance of lesson five on electrical power. Figure 10 depicts the semantic profile for the lesson which is based on the SD coding scores. Overall, most of the lesson consisted of the teacher unpacking and repacking dense scientific concepts (SD score of 5) using more condensed scientific explanations (SD score of 3 and 4). Twice in the lesson the teacher lowers the SD score to 1, where everyday language is used. At the start of the lesson, where the teacher is referring to the previous lesson, there is a single down escalator where a dense concept (SD score of 5 is being briefly unpacked (SD score of 4).

Table 5: Coding description and SD coding score for all utterances of lesson five on electrical power for the novice teacher.

Utterance section	Description of class interaction and subsequent coding choice	SD Scale
1.Yesterday we talked about factors that affect resistance. Can you name them?	Teacher refers to a previously learned concept of factors affecting resistance, which condenses many meanings.	**5**
2. The temperature, diameter of conductor, length of a conductor.	Teacher considers scientifically the multiple factors that affect resistance.	**4**
3.Today's topic is about electrical power. What do you think is electrical power?	Teacher introduces the new concept of electrical power, which condenses many meanings.	**5**
4. Electrical power is related to electrical energy. It is the rate of transfer of electrical energy.	Teacher scientifically unpacks the concept of electrical power considering two variables, rate of transfer and electrical energy.	**4**
5. When we talk about electric energy we talk about the transfer of energy in different forms.	Teacher scientifically unpacks the concept electrical energy by considering two variables, transfer of energy and different forms of energy	**4**
6. For example, the battery in a circuit provides the? …. to light a bulb. The energy. Chemical energy is transferred to light. Or the stove gets hot because the electrical energy is transferred to heat energy	Teacher scientifically describes the types of energy conversions by referring to two examples, a bulb and a stove.	**3**
7. When we refer to a vehicle. What type of energy transfer is taking place? It is chemical energy the fuel that is converted into kinetic or movement energy.	Teacher scientifically describes a type of energy conversion by referring to two components: chemical and kinetic energy	**4**
8. Now electrical power will tell us how fast or slow that energy is converted. In other words, the conversion of energy for a given time. We can say per minute, per hour, per second, per month and so on.	Teacher further scientifically unpacks electric power by considering two parts/variables, energy conversion and time.	**4**

9. We need two things to be able to calculate electrical power in a circuit. let's look at this circuit we are given the voltage and the current. Those are the two things we need to calculate the electrical power.	Referring to a circuit diagram teacher considers two variables (voltage and current) that are part of a formula for calculating electric power.	**4**
10. The formula for electrical power is P Equals V times I.	Teacher introduces the symbolic formula for electric power, which condenses many meanings.	**5**
11. If this current here is two amperes and the voltage is 3 volts the power will be 3 volts times 2 ampere. This will give us 6 watts.	Teachers scientifically applies the formula of electrical power by referring to an example calculation.	**4**
12. You can also use the formula to get the current by dividing power by voltage.	Teacher derives the formula for current using a mathematical operation and using the variables of the electrical power equation.	**4**
13. If the power is twelve watts and the if the current is six amperes your voltage will be 2 volts.	Teachers scientifically applies the formula of current by referring to an example calculation.	**4**
14. What about current? It will be power divided by voltage.	Teacher derives the formula for voltage using a mathematical operation and using the variables of the electrical power equation.	**4**
15. For example here if the power is 8 watts and the voltage is 4 volts the current will be 2 amperes.	Teachers scientifically applies the formula of voltage by referring to an example calculation.	**4**
16. You can see that I am writing the units in every step.	Teacher refers to a single concept (units) by using everyday language.	**1**
17. Try the next three examples to calculate the electric power, voltage and current.	Teacher requests a scientific calculation by referring to multiple variables (electric power, voltage and current).	**4**

18. Why did this person not get the maximum marks? Yes, he did not indicate the units in the second step.	Teacher refers to a single concept (units) by using everyday language.	**1**

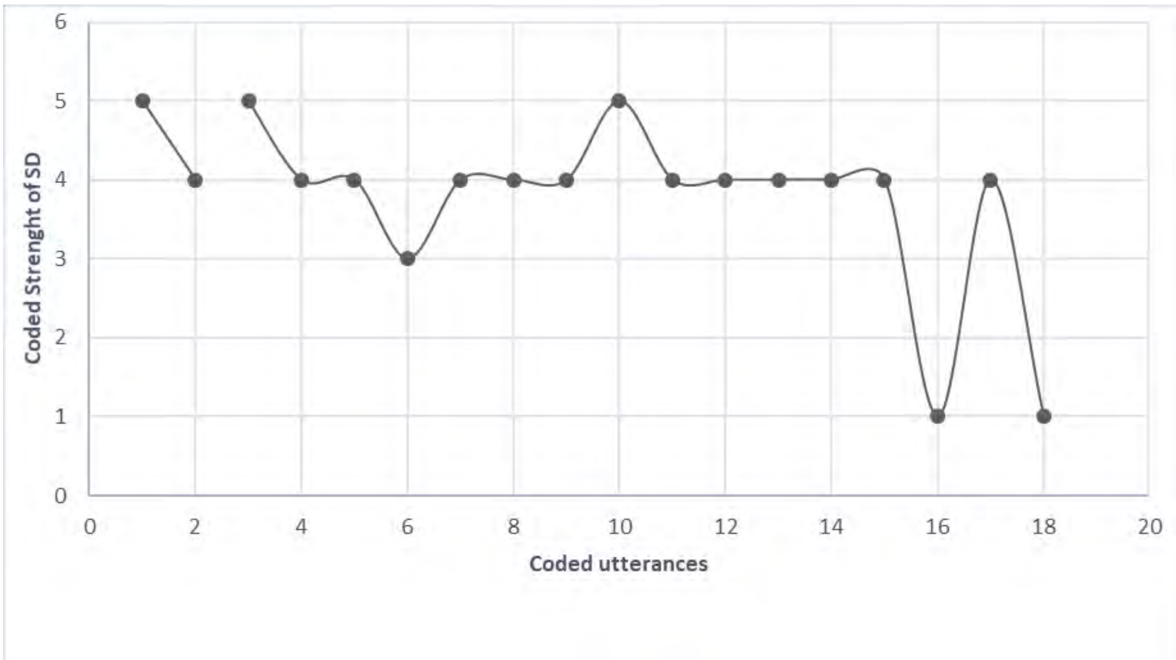


Figure 10: Semantic density profile for lesson five (Novice teacher).

Utterances 1-2 (Down escalator)

At the start of this lesson the teacher refers to a previously learned scientific concept of factors affecting resistance (figure 10), which condenses many meanings and therefore has a SD score of 5. The teacher scientifically unpacks the concept by referring to multiple factors that affect resistance (utterance 2, figure 10) which lowers the SD score to a 4.

Utterances 3-18 (combination of down escalator, semantic waves and high semantic flatlines)

During utterance 3 (figure 10) the teacher introduces a new science concept of electrical power which condenses many meanings, this utterance has a SD code of 5. The teacher scientifically unpacks the dense science concept by considering two variables, rate of transfer and electrical energy, which lowers the SD score to 4 (utterance 4, Figure 10). During utterance 5 the teacher unpacks the concept of electrical energy by considering two variables (transfer of energy and different forms of energy), which has a SD code to 4. During utterance 6 the SD score is further lowered to a 3 as the teacher draws on two science examples to explain types of energy conversions in two examples (light bulb and stove). During utterance 7 the SD score increases to a 4 as the teacher scientifically describes conversion of chemical energy to kinetic energy in a car. The SD score remains at 4 as the teacher scientifically explains the concept of electric power by considering two variables (energy conversion and time), during utterance 8. The SD score 4 is maintained in utterance 9 as the teacher explains, by referring to a circuit diagram, the two variables (voltage and current) that are part of the word formula for electrical power. During utterance 10 the teacher introduces a symbolic formula, which condenses many meanings. This therefore has a SD score of a 5. During utterance 11-15 the SD score is 4 as the teacher further scientifically unpacks the concept of power by the following means: applying the formula for electrical power (utterance 11), using a mathematical operation to derive the formula for current (utterance 12), applying the formula for current (utterance 13), using a mathematical operation to derive the formula for voltage using a mathematical operation (utterance 14), and applying the formula for voltage (utterance 15). Utterance 16 sees the lowering of SD score to a 1 as the teacher refers to single concept of units in the calculation by using everyday language. During utterance 17, which increases the SD score to a 4, the teacher refers to a scientific calculation of the three variables (electric power, voltage and current). During utterance 18 the SD score is again lowered to a 1 as the teacher uses everyday language to refer to the test practice of obtaining maximum marks if units are provided.

Analysis of novice teacher's profile for lesson six

Table 6 outlines the coding description and subsequent SD coding score for each teacher utterance of lesson six on the uses of electricity by the novice teacher. Figure 11 depicts the semantic profile for the lesson which is based on the SD coding scores. Overall, most of the lesson is dominated by low semantic flatlines (SD score of 2). Only once in the lesson did the teacher lower the SD score to 1, where everyday language is used. At the end of the lesson the teacher refers to the upcoming lesson topic, which is scientifically dense and receives a SD score of 5.

Table 6 : Coding description and SD coding score for all utterances of lesson six uses and dangers of electricity for the novice teacher

Utterance section	Description of class interaction and subsequent coding choice	SD Scale
1.Electricity is a wonderful thing. Why am I saying so? Because we benefit a lot from electricity.	Teacher introduces a science concept by drawing on two everyday concepts: electricity and its benefits or uses.	**2**
2. We use electricity in our houses, schools, shops, hospitals, cars and many other places.	Teacher unpacks the concept of uses of electricity pinpointing a number of everyday examples of places where electricity is used.	**2**
3.When we use it can cause problems to all us. It can be dangerous too. What dangers does electricity have?	Teacher introduces another science concept by drawing on two everyday concepts: electricity and its dangers	**2**
4. If electricity is it not handled very well it can burn buildings and if there are people in the buildings they will die.	Teacher unpacks the concept of dangers of electricity using everyday language and two examples of burning of buildings and people dying.	**2**
5. Therefore we must be very careful when we are dealing with electricity. We need to take some precautions.	Teacher continues to unpack the concept of dangers of electricity using everyday language and mentions a single concept of needing precautions.	**1**
6. Electricity can cause shock and death.	Teacher continues to unpack the dangers of electricity using everyday language, mentioning two examples.	**2**
7. When we get shocked the current flows through our bodies and burn the cells to death. This could lead to death.	Teacher unpacks scientifically the concept of electric shock by referring to multiple parts: current flow, bodies, cells and death.	**4**
8. To make electricity safe. We need to some safety measures.	Teacher introduces another science concept by drawing on two everyday concepts: electricity and safety measures.	**2**
9. You must not overload the plugs or outlets. Don't connect too many appliances to one plug. The cables must have good insulation, do not connect and bind the cables, disconnect equipment that you are not using from the plugs, keep your hands dry when you	Teacher unpacks electrical safety through mentioning multiple everyday examples.	**2**

are dealing with power, don't poke your fingers or anything in the plugs.		
10. The other important thing about electricity is that we need to conserve it. Why?	Teacher introduces another science concept by drawing on two everyday concepts: electricity and its conservation.	**2**
11. Producing electricity is expensive. If we use it without wasting, we reduced the cost of making it.	Teacher unpacks the concept electricity conservation using everyday language, drawing on two everyday concepts: waste and cost of production.	**2**
12. How do we conserve electricity? We switch off or unplug all the appliances that we are not using. Turn of the lights when you leave the room. Make use of solar charges for your cellphones. Do not take long warm showers. Those are some of the ways to save electricity.	Teacher uses everyday language to explain conserving electricity, drawing on multiple everyday examples.	**2**
13. This brings us to the end of electricity. Tomorrow we shall do magnetism.	Teacher refers to the next lesson on magnetism, which condenses many meanings.	**5**

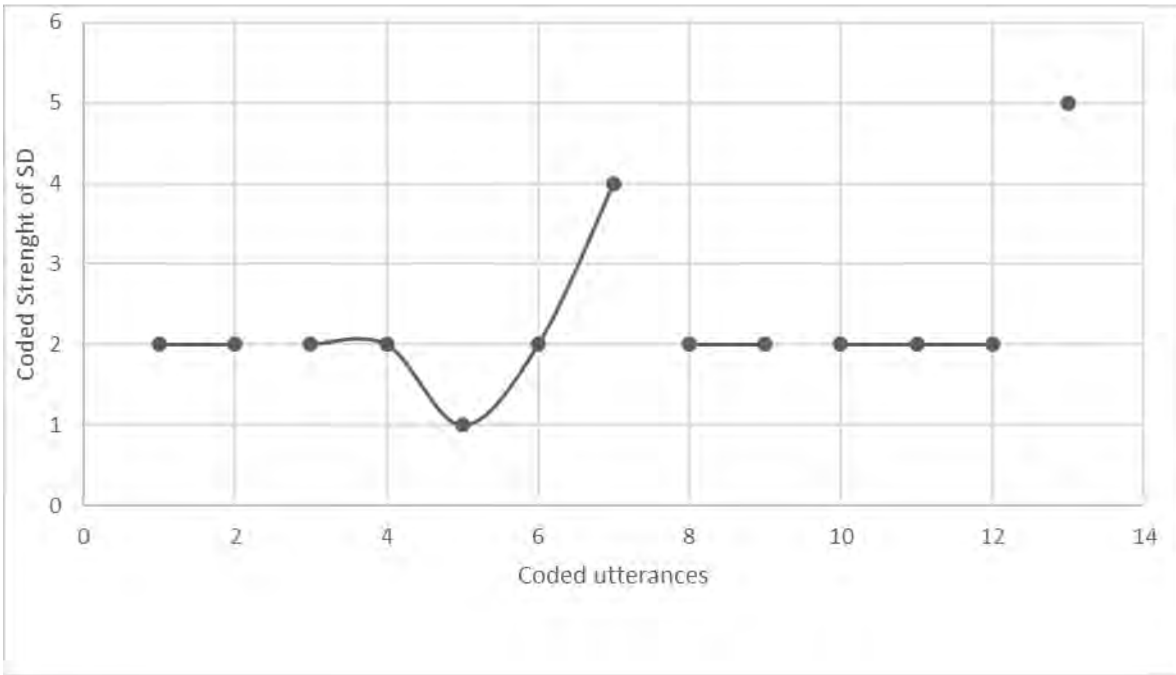


Figure 11: Semantic density profile for lesson six (Novice teacher).

Utterances 1-2 (low semantic flatline)

At the start of this lesson the teacher introduces a new science concept by drawing on two everyday concepts (electricity and its benefits or uses). This has a SD score of a 2. The teacher unpacks the concept of uses of electricity by using everyday examples (utterance 2, figure 11) which keeps the SD score at 2.

Utterances 3-7 (semantic wave)

During utterance 3 (figure 11) the SD score is 2 as the teacher introduces another science concept by drawing on two everyday concepts (electricity and its dangers), During utterance 4 the SD score remains at 2 as the teacher uses everyday language to unpack the dangers of electricity by referring to two such examples. Utterance 5 lowers the SD score to a 1, where the teacher uses everyday language to unpack the dangers of electricity. During utterance 6 the teacher explains the dangers of electricity by referring to two examples, which increases the SD score to 2. Utterance 7 sees further increase of SD score to 4, where the teacher scientifically explains the concept of electric shock by referring to multiple parts, some of which are scientific (current flow, bodies, cells and death).

Utterances 8-12 (low semantic flatline)

During utterances 8-9 the SD score is a 2 as teacher introduces another science concept by drawing on everyday concepts (electricity and its safety; utterance 8) and multiple everyday examples (utterance 9). Utterances 10-12 have a SD score of a 2 as the teacher introduces another science concept of conservation of electricity drawing on two examples (utterance 10), using everyday language drawing on two everyday concepts (waste and cost of production; utterance 11), and by using everyday language drawing on multiple everyday examples (utterance, 12).

Utterance 13 (single reference)

The concluding utterance 15 has a SD score of 5. The teacher refers to the next topic of magnetism, which condenses many meanings.

Analysis of novice teacher's profile for lesson seven

Table 7 outlines the coding description and subsequent SD coding score for each teacher utterance of lesson seven on magnetism by the novice teacher. Figure 12 depicts the semantic profile for the lesson which is based on the SD coding scores. The profile is dominated by semantic waves. Overall, most of the lesson consisted of the teacher unpacking and repacking concepts using both less condensed, everyday explanations (SD score of 2) as well as more condensed scientific explanations (SD score of 3 and 4) . At the end of the lesson the teacher also refers to the following lesson topic, which is scientifically dense and receives a SD score of 5.

Table 7: Coding description and SD coding score for all utterances of lesson seven on magnetism for the novice teacher**.**

Utterance section	Description of class interaction and subsequent coding choice	SD Scale
1. Now let's start with magnetism.	Teacher introduces a new science concept, which condenses many meanings.	**5**
2. The main word in magnetism is magnets. You cannot talk of magnetism without talking of magnets. Magnets attract certain materials.	Teacher unpacks scientifically the concept of magnetism referring to two variables (magnets, materials) and a process (attraction).	**4**

3. We have magnetic materials and non-magnetic materials.	Teacher unpacks scientifically the concept of magnetism by considering two types of materials (magnetic materials and none magnetic materials).	**4**
4. Magnetic materials are materials that are attracted by the magnets.	Teacher scientifically unpacks the concept of none magnetic materials by referring to one process (attraction).	**3**
5. Magnetic materials are also called ferrous materials because they attract magnetic materials.	Teacher scientifically unpacks the concept of magnetic materials referring to its scientific alternative name (ferrous material) and a process (attraction).	**4**
6. Non-magnetic materials are materials that are not attracted by magnets.	Teacher scientifically unpacks the concept of none magnetic materials by referring to one process (non-attraction by magnets).	**3**
7.Those materials that are attracted by magnets, there is something special about them. They contain iron.	Teacher scientifically explains why magnetic material are attracted by magnets by referring to one element/part (iron).	**3**
8. Examples of materials that are attracted by magnets are nickel, iron, steel, cobalt.	Teacher considers multiple science examples of magnetic materials	**3**
9. The non-ferrous material are materials that are not attracted by the magnets.	Teacher scientifically explains why some materials are not attracted by magnets based on one element/part (iron).	**3**
10. Example are glass, plastics, papers, copper, and they do not contain iron.	Teacher considers multiple everyday examples of non-ferrous materials.	**2**
11. We have two types of magnets. A horse shoe magnet (this one) and a bar magnet (this one).	Teacher unpacks in everyday language the two types of magnets based on their shape: horseshoe and bar	**2**
12. The bar magnet has two poles as you can see. The north pole and the south pole. The horse shoe is difficult to see the poles. Like poles repel and unlike poles attract.	Teacher unpacks scientifically the two types magnets by referring to two parts (north and south poles) and a process (repel).	**4**

13. Magnets attract magnetic materials or ferrous materials.	Teacher refers back to ferrous materials by considering a process (attraction by magnets).	**3**
14. And a free suspended magnet will point in the north south direction. For example, the one in the compass. The compass arrow points at the north direction or south direction.	Teacher scientifically unpacks the concept of magnets by referring to multiple variables (north and south directions, compass).	**4**
15.The magnets are having magnetic fields. What are the magnetic fields?	Teachers refers to a new science concept of magnetic fields, which condenses many meanings.	**5**
16. They are around the magnet. This is the area around the magnet whereby the force of the magnets can be experienced or can be exerted.	Techer scientifically unpacks the concept of magnetic field by considering two parts/ variables (area around magnet, force).	**4**
17. We can draw magnetic field lines around magnetic fields.	Teachers unpacks scientifically magnetic fields by introducing the single concept of lines	**3**
18. And the magnetic lines move from the north pole to the south pole of the magnet. We can confirm this with an experiment whereby we use a compass and the iron filings. Iron filings will show us the presents of magnetic field around the magnet. And the compass is having the arrows which shows the poles of the magnets. If you put it on the side or end of the pole it will point to north because magnetic field lines they move from north to south poles.	Teacher scientifically unpacks the concept of magnetic field lines by referring to multiple variables (movement, iron filings, compass, north and south poles).	**4**
19.You have seen from the experiment the way the iron filings arrange themselves. They indicate the magnetic field line.	Teacher further unpacks the concept of magnetic field lines by referring to one variables (arrangement of iron filings).	**3**

20. You have to know how to draw the magnetic field lines. With the arrows showing the directions. North and north field lines bent not touching one another. This is the same with south and south. South and north the field lines join one another.	Teacher describes using everyday language the concept of field lines by referring to a number of component (arrows, direction, lines joining, bending).	**2**
21.Tomorrow we shall talk about electromagnetic induction.	Teacher refers to the next topic "electromagnetic induction", which condenses many meanings.	**5**

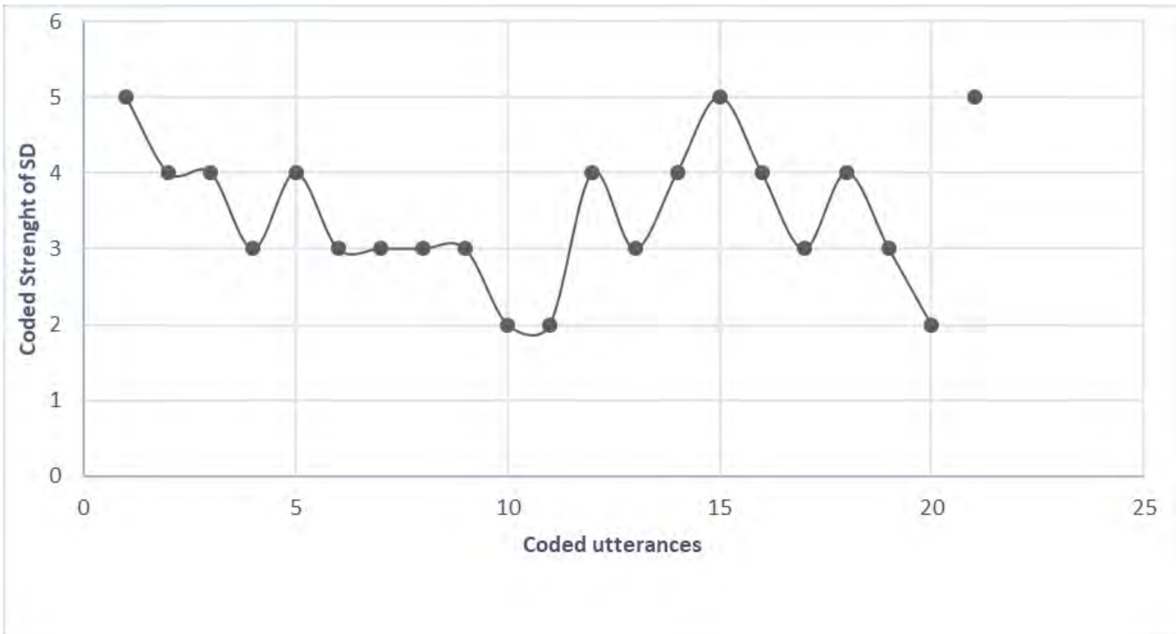


Figure 12: Semantic density profile for lesson seven (Novice teacher).

Utterances 1-20 (semantic waves)

At the start of this lesson the teacher introduces a new scientific concept of magnetism (figure 12), which condenses many meanings and therefore has a SD score of a 5. Utterances 2 and 3 lower the SD score to a 4 as the teacher scientifically unpacks the concept by referring to multiple components (magnets; magnetic and non-magnetic materials, attraction). Utterance 4 sees the lowering of SD score to a 3 as the teacher unpacks the concept of non-magnetic materials by referring to one process (attraction). In utterance 5 the teacher scientifically explains the science concept of magnetic material by considering an alternative name (ferrous material) and a process (attraction). This increases the SD score to 4. Utterances 6 -9 again lower the SD score to a 3 whereby the teacher scientifically unpacks the concepts of magnetic and non-magnetic materials by the following means: referring to a process (non-attraction by magnets; utterance 6), one element (iron; utterance 7 and 9), and referring to multiple examples (utterance 8). Utterances 10 and 11 further lower the SD score to 2 as the teachers refers to everyday examples of materials not attracted by magnets (plastic, paper, copper; utterance 10) and by using everyday language to consider two types of magnets (bar and horseshoe; utterance 11). The SD score increases again to a 4 in utterance 12 as the teacher again reverts back to more scientific explanations of the two types of magnets by referring to two parts (north and south poles) and a process (repel). In utterance 13 the teacher refers to ferrous material by considering a single process (attraction by magnets), resulting in a SD score of 3. During utterance 14 the SD score again increases to a 4 as the teacher scientifically explains the concepts of magnets by referring to multiple variables (north and south directions, compass). During utterance 15 the teacher introduces a new science concept of magnetic field, which condenses many meanings. This has a SD score of 5. Teacher scientifically unpacks the dense concept of magnetic field in utterance 16 by considering two variables (area around a magnet and force), reducing the SD score to 4. A further decrease in SD score to 3 is observed with utterance 17 when the teacher scientifically unpacks the concept of magnetic field by introducing a single concept of magnetic field lines. The SD score increases again to 4 in utterance 18 as the teacher scientific explains the concept of magnetic field lines by drawing on multiple variables (movement, iron fillings, compass, north and south pole). Utterance 19 sees the SD score decreasing to 3 as the teacher unpacks the concept of magnetic field lines referring to one variable (arrangement of iron filings). The SD score decreases to 2 in utterance 20 as the teacher uses everyday language to explain the concept of magnetic field lines by drawing on multiple variables (arrows, direction, touching, joining and bending).

Utterances 21 (single reference)

The concluding utterance 15 has a SD score of a 5. The teacher refers to the next topic of electromagnetic induction, which condenses many meanings.

Appendix B: Coding description and SD coding score for all utterances of lesson two to seven for the experienced teacher.

Analysis of experienced teacher's profile for lesson two

Table 10 below outlines the coding description and subsequent SD coding score for each utterance of the experienced teacher in lesson two, which is based on the concept of voltage. The semantic density profile for this lesson, based on the SD coding score, is depicted in Figure 14. Overall, most of the lesson consisted of the teacher unpacking and repacking dense scientific concepts (SD score of 5) using more condensed scientific explanations (SD score of 3 and 4). Once in the lesson the teacher lowers the SD score to 2, where everyday examples are used.

Table 10: Coding description and Semantic density coding score for all utterances of lesson two on voltage for the experienced teacher.

Utterance section	Description of class interaction and subsequent coding	SD score
1. What is voltage or potential difference?	Teacher asks the definition of "voltage/potential difference" which condenses many meanings.	**5**
2. Voltage is the ability to drive the charge around the circuit. The ability to drive a charge around the circuit. We said current is the flow of charge. The voltage is the ability of the conductor .	Teacher explains scientifically the definition of voltage by considering four variables/parts: current, flow of charge, circuit and conductor.	**4**
3. The ability of the source, the battery or the cell to drive the charges around the circuit.	Teacher further explains scientifically what voltage is referring to one process – charge being driven around a circuit.	**3**
4. So, this potential difference is the one which is called the voltage.	Teacher refers back to the idea that voltage and potential difference mean the same thing. Both phrases condense much many meanings.	**5**
5. The cell is having two terminals - the positive and the negative.	Teacher explains scientifically that the cell contains two distinct parts (positive and negative terminals).	**4**
6. Now these terminals are having different potentials.	Teacher refers scientifically to one variable that exist between the two terminals of a cell: potential difference.	**3**

7. So, because the electricity or the charges flow from negative to positive then one terminal will have more force to push the charges to another terminal which is having a low force or the low ability.	Teacher explains scientifically the potential difference between the two terminals of a cell by referring to four variables/parts: electricity, flow of charges, force and potential.	**4**
8. That difference is the one that make the charges to flow along the conductor.	Teacher explains scientifically that potential difference makes charges flow in the conductor. Teacher links two variables (flow of charges along the conductor to the potential difference).	**4**
9. Now there is a difference between voltage in series and voltage in parallel.	Teacher scientifically enumerates the two distinct types of circuits (parallel and series) and indicates that there is difference in potential difference between them.	**4**
10. In series the voltage is different.	Teacher describes scientifically the voltage in one type of a circuit (series circuit).	**3**
11. You know in series the current is the same but in series the voltage is different.	Teacher describes scientifically the circuit in series in terms of two variables (current and voltage).	**4**
12. While in parallel the voltage is the same at all points.	Teacher describes scientifically the voltage in one type of a circuit (parallel circuit).	**3**
13. So in series the voltage across individual component is equal to voltage in the whole circuit.	With reference to a diagram teacher continues to describe scientifically the voltage in series in more detail using a mathematical operation.	**4**
14. Here you can read the voltage in series circuit.	Teacher refers to a diagram regarding a single variable, voltage in series.	**3**
15. While in parallel the voltage across the branch is equal to the voltage across the battery.	With reference to a diagram teacher describes scientifically the voltage in parallel using a mathematical operation.	**4**
16. Here you can read the voltage in parallel circuits.	Teacher refers to a diagram regarding a single variable voltage in parallel.	**3**
17. Voltage can be calculated by using a formula.	Teacher uses everyday language so suggest that a formula (which has multiple parts) can be used to calculate voltage.	**2**

18. The formula is V equals I times R.	Teacher refers to the symbolic formula for voltage which condenses many meanings.	**5**
19. Say here the resistance is five Ohms and the current is two Amperes the voltage will be ten Volts.	With reference to a diagram teacher unpacks scientifically the different parts of the formula of voltage by using example.	**4**

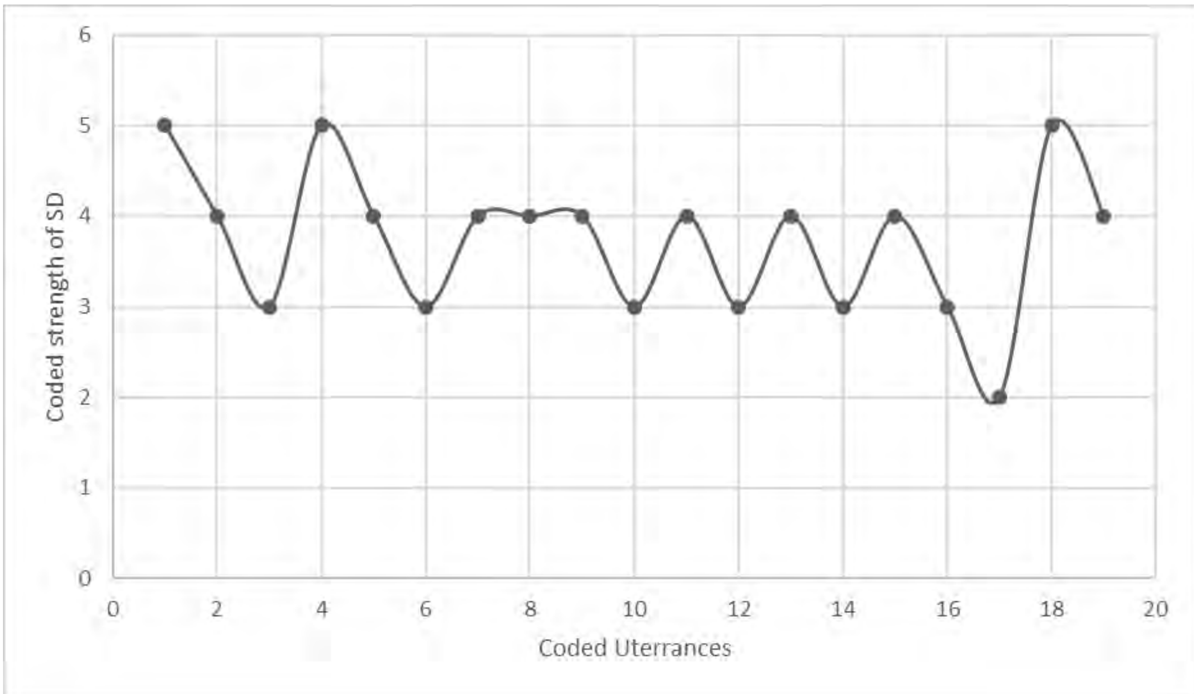


Figure 14: Semantic density profile for lesson two (experienced teacher) Utterances 11-19 (semantic waves)

At the start of the lesson the teacher introduces a new scientific concept of voltage (Table 10 and Figure 14), which condenses many meanings and therefore has a high SD score of a 5. Utterance 2 lowers the SD score from a 5 to a 4 as the teacher scientifically define the concept by considering four variables (current, flow of charge, circuit and conductor). Utterance 3 further lowers the SD score to a 3 as the teacher explains the concept by referring to a single process (charge being driven around the circuit). Utterance 4 sees the SD score increasing to 5 as the teacher scientifically equates voltage to potential difference. Both concepts (voltage and potential difference condense many meanings). Utterance 5 lowers the SD score to a 4 as the teacher scientifically unpacks the dense concept of potential difference by considering two terminals of a cell (negative and positive terminals). Utterance 6 sees a further lowering of the SD score to a 3 as the teacher scientifically refers to one variable (potential difference) that exist between the two terminals of a cell. Utterances 7,8 and 9 increases the SD score to 4. During those utterances the teacher scientifically unpacks the dense concept of potential difference by a number of means: by considering four variables that exist between the two terminals of a cell - (electricity, of charges, force and potential difference (utterance 7): linking the two variables – potential difference and flow of charge (utterance 8); naming the two types of circuits and indicating that the potential difference in those circuits differ (utterance 9). Utterance 10 lowers the SD score to 3 as the teacher scientifically describes the voltage in one type of a circuit (series circuit). During Utterance 11 the teacher describes scientifically the circuit in series by referring to two variables (current and voltage), which increases the SD score to 4. Utterance 12 lowers the SD score to 3 as the teacher scientifically describes the voltage in another type of the circuit (parallel circuit). Utterance 13 sees the increase of the SD score to 4 as the teacher uses a mathematical operation to describe the voltage a series circuit. Utterance 14 lowers the SD to 3 as the teacher refers to a diagram of a series circuit considering a single variable (voltage). The SD score increases again to 4 during utterance 15 as the teacher uses a mathematical operation to describe the voltage a parallel circuit. Utterance 16 further lowers the of SD score to 3 as the teacher refers to a diagram of a parallel circuit considering a single variable (voltage). During utterance 17 the teacher uses everyday language to suggest that a formula can be used to calculate the voltage, this further lowers the SD score to a 3. During utterance 18 the teacher refers to a symbolic formula for voltage which condenses many meanings and therefore gains a SD score of 5. The concluding utterance sees the lowering of the SD score to a 4 as the teacher scientifically unpacks, using an example, the different parts of the formula.

Analysis of experienced teacher's profile for lesson three

Table 11 below outlines the coding description and subsequent SD coding score for each utterance of the experienced teacher in lesson three, which is based on the concept of resistance. The semantic density profile for this lesson, based on the SD coding score, is depicted in Figure 15. Overall, most of the lesson consisted of the teacher unpacking and repacking dense scientific concepts (SD score of 5) using more condensed scientific explanations (SD score of 3 and 4).

Table 11: Coding description and Semantic density coding score for all utterances of lesson three on electrical resistance for the experienced teacher.

Utterance section	**Description of class interaction and subsequent coding choice**	**SD score**
1.What is resistance?	Teacher introduces a science concept of resistance, which condenses many meanings.	**5**
2.The opposition to the current flow or the force which oppose the movement of the charges along the conductor.	Teacher explains scientifically what resistance is by considering multiple variables/parts (current flow, force, charges).	**4**
3.Resistance is measured in ohms and it is measured using the ohm meter.	Teacher explains the measurement of resistance scientifically by mentioning two components: the units (ohms) and the instrument (ohm meter) used.	**4**
4.It can also be determined from the quantity of current and voltage by using the formula voltage divided by current.	Teacher names scientifically the two variables voltage and current, arranging them into a word formula for calculation of resistance.	**4**
5.And then the resistance in parallel and resistance in series.	Teacher refers scientifically to two types of resistance (parallel and series)	**4**
6. In series the total resistance of the resistor is equal to the sum of resistance of individual resistors	Teacher refers to a mathematical operation on how to determine the total resistance in a series circuit.	**4**
7.Let's say this is a series circuit and the total resistance here is equal to the resistance here.	Teacher explains scientifically with the aid of example how to determine the resistance in a series circuit.	**3**
8.That is why we have a formula that says RT equals to R1 plus R2. You just add the resistance in the circuit.	Teacher refers to symbolic representation of formula that is used to calculate the resistance in	**5**

	series, which condenses many meanings.	
9.But resistance in parallel we have the formula which is one over RT which is the total, which is 1 over R1 plus 1 over R2 it depends how may resistors are there.	Teacher moves to a symbolic representation of the formula that is used to calculate the resistance in parallel. The formula condenses many meanings.	**5**
10.If there are four you go on like that. Then what you do you look for the common denominator of the number for example you say R1 there is 3 ohms and Resistor two there is 2 ohms and then you look for common denominator of three and two which is six. Three goes in six how many times? Two plus three is? and then you do reciprocal and the answer will be 1.2 ohms.	Teacher explains scientifically the procedures, referring to an example, on how to calculate the resistance in parallel and teachers does some calculations.	**4**
11.Now can we end with the factors that are affecting resistance.	Teacher introduces the next topic – (factors affecting resistance) which condenses many meanings.	**5**
12.The factors that affect resistance are temperature of the conductor, the diameter of the conductor, the type of the conductor, the diameter and cross sectional area of the conductor and the length of the conductor.	Teacher considers scientifically the multiple factors linked with conductors that affect resistance.	**4**
13.How does those three things you have mentioned affects the resistance? Let's consider the temperature.	Teacher considers one factor (temperature of conductor**)**, that affects resistance.	**3**
14.As temperature increases the resistance also increases and low the temperature the lower the resistance and the relationship between this two is called they are directly proportional.	Teacher describes scientifically the relationship between two variables (temperature and resistance).	**4**
15.The type of a conductor how does it affect the resistance?	Teacher considers via questioning another factor (type of conductor) that affects resistance.	**3**
16.Materials that are good conductors they have low resistance and they have low temperature.	Teacher describes scientifically the relationship between three variables: good conductors, temperature and resistance.	**4**

17.Can you give me example of one material which is a good conductor of electricity? And one with low resistance.	Teacher asks learners to give examples of good conductors of electricity and those with low resistance. The question refers to one example based on a relationship between two variables: (good conductors and low resistance).	**4**
18.Nichrome wire.	Teacher confirms the example which is a scientific one.	**3**
19.We also have one factor which is the length of the conductor.	Teacher considers another factor (length of conductor) that affects resistance.	**3**
20.The longer the conductor the higher the resistance and they are also directly proportional.	Teacher describes scientifically the relationship between two variables: resistance and length of the conductor.	**4**
21.And we also have the diameter or the cross sectional area of the conductor. How does it affect the resistance?	Teacher considers another factor (diameter of conductor) that affects resistance.	**3**

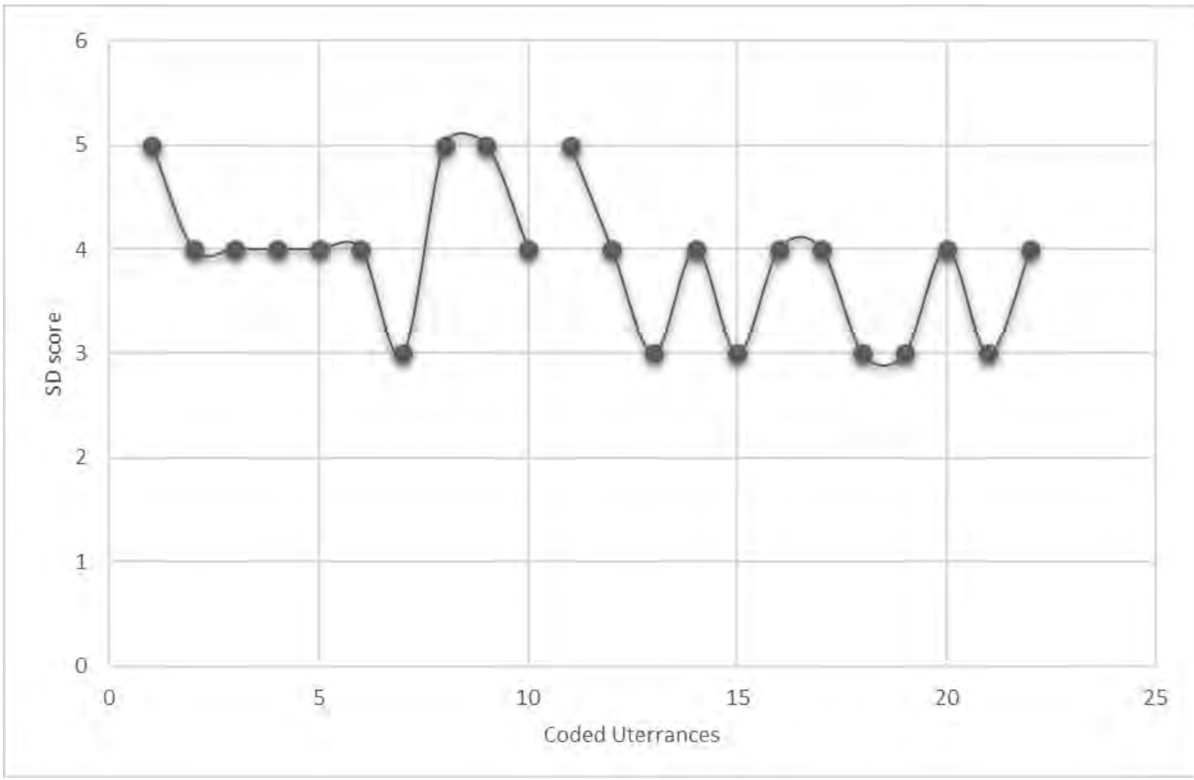


Figure 15: Semantic density profile for lesson three (experienced teacher)

Utterances 1-10 (combination of semantic waves and a flatline)

At the start of the lesson the teacher introduces a new scientific concept of resistance which condenses many meanings, hence is has a SD score of 5 (Table 11 and Figure 15). Utterances 2 ,3,4,5 and 6 lowers the SD score from a 5 to a 4. During those utterances the teacher scientifically unpacks the dense concept of resistance by a number of means: referring to multiple parts of current flow, force and charge (utterance 2); referring to the units and the instrument (utterance 3); arranging two variables, voltage and current, into a word formula for calculation of resistance (utterance 4); by referring to two types of resistance (utterance 5) and referring to a mathematical operation on how to determine the total resistance in series circuit (utterance 6). Utterance 7 lowers the SD score to 3 as the teacher scientifically explains, with an aid of an example, how to calculate the resistance in series circuit. Utterances 8 and 9 increase the SD score to 5 again as the teacher refers to symbolic representation of formulae to calculate the resistance in series (utterance 8) and parallel (utterance 9). Both formulae condense many meanings. The SD score decreases to a 4 during utterance 10 as the teacher uses an example to scientifically explain the procedures on how to calculate the resistance in parallel and teacher does some calculations

Utterances 11-22 (semantic waves)

During utterance 11 (Table 11 and Figure 15) the teacher introduces the next topic of factors that affect resistance, which condenses many meanings and therefore receives a SD score of 5. Utterance 12 lowers the SD score to a 4 as the teacher scientifically unpacks the topic by naming the different factors (temperature of conductor, type of conductor, diameter and cross section area of a conductor and the length of a conductor. The SD score further decreases to a 3 in utterance 13 as the teacher considers one factor that affects resistance (temperature of a conductor). Utterance 14 sees the increase in SD to 4 as the teacher scientifically describes the relationship between the two variables (temperature and resistance). During utterance 15 the SD is lowered to a 3 again as the teacher scientifically refers, via a question, to another factor that affects resistance (type of a conductor).Utterance 16 and 17 increase the

SD score to 4 again as the teacher scientifically describes the relationship between three variables- good conductors, temperature and resistance (utterance 16) and asks a question referring to one example based on relationship between two variables – good conductors and low temperature (utterance 17). Utterances 18 and 19 lower the SD score to a 3 as the teacher confirms one scientific example of a good conductor (utterance 18) and considers another factor that affects resistance- length of a conductor (utterance 19). During utterance 20 the teacher describes scientifically the relationship between to variables (resistance and length of a conductor), which increases the SD score to a 4. Utterance 21 again lowers the SD score to a 3 as the teacher considers another factor that affects resistance (diameter of a conductor). Utterance 20 sees the increase of SD score to a 4 as the teacher scientifically describes the relationship between two variables (diameters of conductors and resistance).

Analysis of experienced teacher's profile for lesson four

Table 12 below shows the coding description and subsequent SD coding score for each utterance experienced teacher utterance of lesson four, which is based on the concept of relationship between current and voltage. The semantic density profile for this lesson, based on the SD coding score, is depicted in Figure 16. The profile is characterized by a strongly scientific approach with a down escalator and high semantic density waves (SD scores of 3 and more). At the beginning of the lesson there is a single high semantic density down escalator, when a teacher briefly unpacks a dense concept (SD score 5 to 4). Later in the lesson the teacher draws on everyday language and examples to unpack dense concepts (SD score 1 and 2), two of which create semantic waves that go across the SD range (SD scores 5 to 1).

Table 12 : Coding description and Semantic density coding score for all utterances of lesson four on resistance (V/I relationship) for the experienced teacher.

Utterance	**Description of class interaction and subsequent coding choice**	**SD scale**
1. Yesterday we have been talking about factors that affecting resistance.	Teacher introduces previously learned concepts 'factors that affect resistance', which condenses many meanings.	**5**

2. There are four of those factors. Namely- temperature of, the length of the conductor, the diameter of the conductor and type of the conductor. And you must be able to explain how these conductors affect the resistance.	Teacher unpacks scientifically the concept of 'factors that affect resistance' by naming the four constituent variables and reminds learners to explain how those factors affect resistance.	**4**
3. The calculation for resistance in parallel and series we did it yesterday.	Teacher refers to two previously learned concepts 'resistance in parallel and resistance in series'. The concepts condense many meanings.	**5**
4. But today we are going to talk about the relationship between current and voltage in electrical conductor.	Teacher considers a new concept 'relationship between current and voltage'. The concept condenses many meanings.	**5**
5. And yesterday we learned what is current. What is current?	Teacher refers to the previously learned concept 'current', which condenses many meanings.	**5**
6. Current is a flow of charge. And voltage is the potential difference that exist between two point is a circuit.	Teacher explains scientifically the concept 'current' in terms of flow of current-a single process and 'voltage' in terms existence of potential difference between two points in a circuit – also referring to a single variable.	**3**
7. Therefore, you won't have current if we don't have potential difference.	Teacher explains scientifically the relationship between the two concepts, current and potential difference.	**4**
8. Potential difference is the force which allows flow of charges along the conductor forcing the charges to move and that is what we call current.	Teacher explains scientifically what 'current' is by referring to three variables (potential difference, force and flow of charge, current).	**4**
9. And now, this means that if there is a force. We say potential difference is the force that drives the current.	Teacher continues to explain scientifically "potential difference" in terms of two variables, current and force.	**4**
10. Let say if the potential difference is high how does it affect the current?	Teachers asks a science question related to relationship between the two variables, current and potential difference.	**4**
11. The current will also be high. If the voltage is low the current will also be low. So, that is the relationship we are going to focus on today.	Teachers explains scientifically the relationship between the two variables, current and voltage.	**4**

12. And in some conductors, good conductors of electricity if current increases voltage will also increase or if voltage increases current will also increase.	Teachers explains scientifically the relationship between current and voltage bringing in a third variable which is a conductor.	**4**
13. So, that is what we call directly proportional to each other.	Teacher makes a science conclusion based on previous scientific explanations which contained two or more variables.	**3**
14. If the current and voltage are directly proportional to each other, then we say they obey the ohm's law.	Teacher links the concept of direct proportionality to the concept 'ohm's law', which condenses many meanings.	**5**
15. What does the ohm's law say?	Teacher asks a question about 'ohm's law', which condenses many meanings.	**5**
16. In a metallic conductor at a constant temperature the current is directly proportional to the potential difference.	Teachers explains scientifically the relationship between current and electricity bringing in fourth variable, temperature.	**4**
17. The current through a metallic conductor at a constant temperature is directly proportional to the potential difference because in ohmic conductors the resistance is always constant.	Teacher explains scientifically the relationship between current and potential difference by considering four variables (metallic conductor, constant temperature, ohmic conductors and resistance).	**4**
18. What change the voltage or flow of current?	Teachers asks a science question related to change of current flow or voltage. Two variables are considered (voltage and current).	**4**
19. The flow of current is changed by resistance. If the resistance is high or changing the current also changes.	Teacher explains scientifically the change of current in terms of one variable, which flow of resistance.	**3**
20. And that is the reason why we talked about the factors that affect electricity or the flow of current.	Teacher refers to a new concept 'factors that affect electricity or flow of current", which is a dense concept.	**5**
21. We say the high the temperature the more the resistance, and the resistance is the one which is reducing current.	Teacher describes scientifically the relationship between the three variables - resistance, current and temperature.	**4**

22. So, if the temperature was low at first, then the current will be high. Now, if the temperature increases the current will also…? Will also reduce.	Teacher further describes scientifically the relationship between the three variables - temperature, resistance and current.	**4**
23. You used to see when you are charging the phone, after sometime the charger is hot. So, that is the temperature of the conductor we are talking about.	Teacher explains a science concept 'temperature' referring to an one everyday example of charging a cell phone.	**1**
24. And the conductors now, not all electrical conductors obey the ohm's law.	Teacher considers another concept 'conductor' with relation to ohm's law. The concept condenses many meanings.	**5**
25. Because some conductors when charges pass through them they get hot, these conductors that change the temperature are non-ohmic conductors.	Teacher explains scientifically what non-ohmic conductors are by considering two variables (charge, temperature).	**4**
26. Non- ohmic conductors are for example the filaments of the bulb. As it gets hot the current is also low.	Teacher refers to one every day example (a filament in a bulb) to illustrate what a non- ohmic conductor is.	**1**
27. There are also materials that obey ohm's law and we call them the ohmic conductors.	Teacher identifies scientifically the second type of conductors, the ohmic conductors referring to Ohm's law.	**3**
28. Ohmic conductors are good conductors of electricity for example….?	Teacher explains scientifically what ohmic conductors are by referring to one variable, electricity.	**3**
29. Copper, nichrome wire.	Teacher names two science examples of ohmic conductors.	**3**
30. We can tell from the graph that a conductor is ohmic or non ohmic conductor.	Teacher hints towards a graph, which condenses many meanings.	**5**

31. Let's say here there is voltage on the y-axis and current (I) on the x-axis. The graph for ohmic conductor will go straight, because the voltage and the current are directly proportional.	Teacher explains scientifically what an ohmic conductor is by referring to two variables, current and voltage, on the graph. Teacher mentions that they are directly proportional.	**4**
32. Here we can see that the current increases as the voltage also increases.	Teacher explains scientifically the relationship between the two variables on the graph, current and voltage.	**4**
33. This only happens in ohmic conductors for example copper, copper wire, nichrome wire.	Teacher explains science concept by using multiple science examples of ohmic conductors.	**3**
34. Now how does a graph of non-ohmic conductor looks like?	Teacher asks question related to a graph of a non-ohmic conductor, which condenses many meanings.	**5**
35. It is not straight like this one.	Teacher describes scientifically the shape of a non-ohmic conductor by referring to the shape of the graph (single variable), which infers two variables (voltage and current) are involved.	**4**
36. Now we have the graph which represents the a non ohmic conductor. Here we have voltage in volt.	Teacher points to a science graph (inferring two variables) of a non-ohmic conductor and further refers to another variable (unit of voltage).	**4**
37. Always write the name of the quantity and the unit.	Teacher explains the procedure with regards to quantity and units-everyday language drawing on two parts (quantity and unit).	**2**
38. Now the non ohmic conductors do not obey the ohm's law. The voltage will not be directly proportional to the current. As long as it is not straight as long as it bent down or up. It is a non ohmic conductor.	Teacher describes scientifically a non-ohmic conductors referring to five variables(ohms law, voltage, current, shape of the graph).	**4**
39. Why does it give a drawing or curve like this? It is indirectly proportional.	Teachers ask a science question about the shape of the graph, which infers two variables (voltage and current) are involved.	**4**

40. Even if the voltage increases. You can see from the graph the voltage was increasing from the beginning. And here maybe the temperature increases and it affects the current. Even if the voltage is high the current will not increase because there is high resistance which is opposing the flow of charges.	With reference to the graph teacher explains scientifically the concept indirect proportionality referring to five variables (voltage, temperature, current, resistance, flow of charge).	**4**
41. Here at first it was obeying the ohms law up to here to here and from three up to four here you can see that the voltage is increasing, from three to four the current is just zero point five.	Teacher explains scientifically referring to two variables, current and voltage, using the graph how the conductor obeys/disobeys ohm's law.	**4**
42. This means there is a force that opposing the movement of charges. There is a high resistance. Therefore, the current will not be high. The current can be constant or also low.	Teacher consider four variables (force, movement of charge, resistance) to scientifically explain the shape of a graph of a non-ohmic graph.	**4**
43. Non- ohmic conductors we have bulbs. They do not obey ohm's law.	Teachers names an everyday example (a bulb) to explain a science concept of non-ohmic conductors.	**2**
44. You can also do this by calculating. You can have a table of current and voltage and then you calculate resistance.	Teacher names scientifically the two variables, current and voltage, that are needed to calculate the resistance, leading to a word formula.	**4**
45.The formula to calculate the resistance is Voltage divided by current.	Teacher condenses two variables, voltage and current, to form a word formula for resistance. The formula condenses many meanings,	**5**
46. What you need to know is that if you calculate the resistance at any point here you should get the same answer, for ohmic conductor.	Teacher explains scientifically that resistance at any given point of on a graph of an ohmic conductor will be the same. Teacher uses single variable, resistance, to explain ohmic conductors.	**3**
47. But here you will not get the same answer. And that means that that conductor is an non ohmic conductor.	Teacher explains scientifically why the conductor is called non-ohmic by referring to calculations(example) from the graph. Teacher uses single variable, resistance, to explain non-ohmic conductors.	**3**

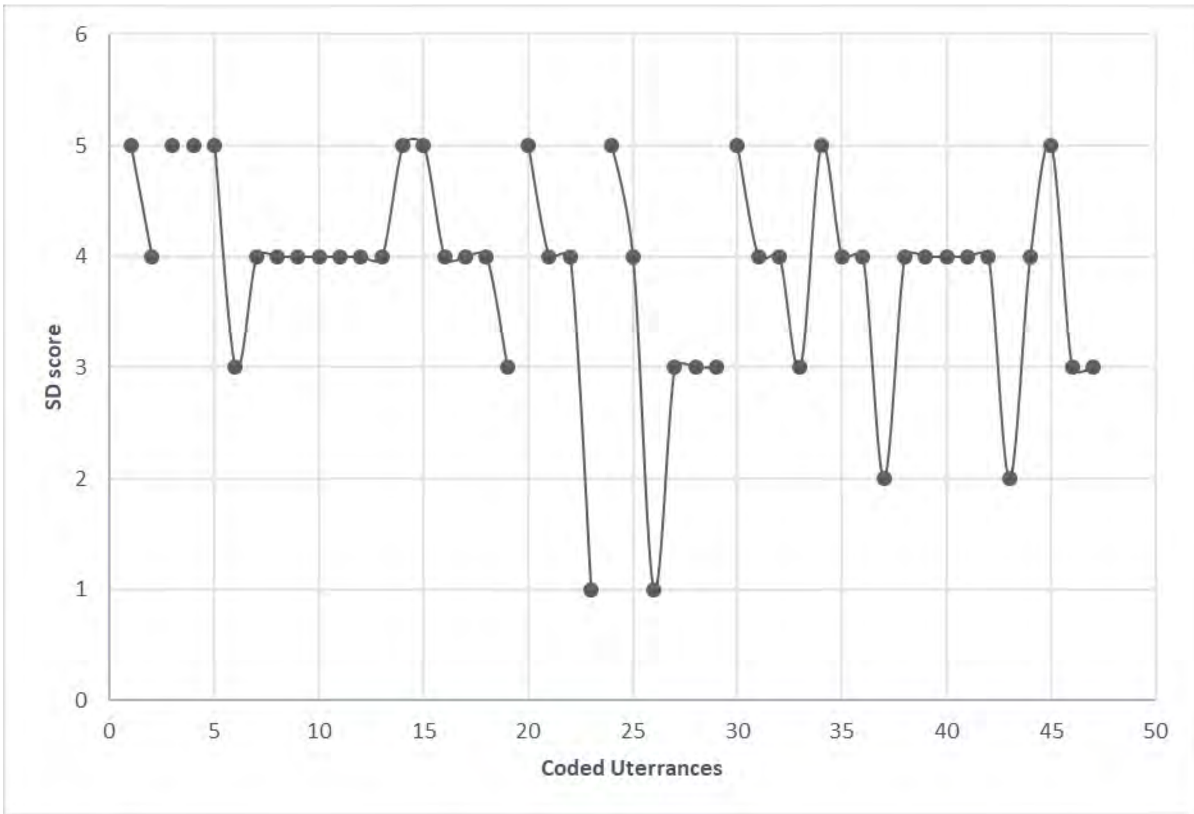


Figure 16: Semantic density profile for lesson four (experienced teacher)

Utterances 1-2 (down escalator)

At the start of the lesson the teacher introduces a previously learned scientific concept of factors that affect the resistance, which condenses many meanings, hence it has a SD score of 5 (Table 12 and Figure 16). Utterance 2 sees the lowering of SD score to a 4 as the teacher briefly unpacks the dense concept of factor affecting resistance.

Utterances 3-4 (single references)

Utterances 3 and 4 have SD scores of 5 (Table 12 and Figure 16) as the teacher refers to a previously learned scientific concepts of resistance in parallel and series circuits (utterance 3) which condenses many meanings and introduces a new science concept of relationship between current and voltage (utterance 4), which also condenses many meanings.

Utterances 5-19 (semantic waves)

During utterance 5 the teacher refers to a previously learned concept of current which condenses many meanings, hence it has a SD score of 5 (Table 12 and Figure 16).

Utterance 6 sees the lowering the SD score to a 3 as the teacher scientifically explains the concept of current referring to a single process (flow of charge). Utterances 7,8,9,10,11 and 12 increase the SD score to a 4 as the scientifically explains: the relationship between two variables- current and potential difference (utterance 7); what current is by referring to three variables - potential difference, force and flow of charge (utterance 8); potential difference referring to two variables- current and force (utterance 9); via science question the relationship between the two variables- current and potential difference (utterance 10); the relationship between two variables -current voltage(utterance 11) and considers a third variable –conductor (utterance 12). Utterance 13 keeps the SD score at 4 as the teacher makes a science conclusion based on previous scientific explanation of direct proportionality, which contains two or more variables. During utterance 14 and 15 the SD score increase to 5. During those utterances teacher links the concept of direct proportionality to the concept of "Ohm's law" (utterance 14) and asks a question about "Ohm's law" (utterance 15). Both utterances contain a dense concept "Ohm's law" which condenses many meanings. Utterances 16 and 17 lower the SD score to 4. During those utterances the teacher scientifically explains: the relationship between current and electricity bringing in temperature as a fourth variable (utterance 16); the relationship between current and potential difference by considering four variables- metallic conductors, constant temperature, ohmic conductors and resistance (utterance 17). Utterance 18 keeps the SD score at a 4 as the teacher asks a science question considering two variables (current and voltage). Utterance 19 sees the lowering of SD score to a 3 as the teacher scientifically explains change in current in terms of one variable (flow of charge).

Utterances 20-23 (semantic wave)

Utterance 20 gains a SD score of 5 as the teacher introduces a new concept (factors that affect the flow of electricity or flow of current), which condenses many meanings (Table 12 and Figure 16). Utterance 21 and 22 lower the SD score to 4 as the teacher scientifically describes the relationship between: the three variables -resistance, current and temperature (utterance 21); two variables -temperature and current (utterance 22). Utterance 23 sees the lowering of SD score to a 1 as the teacher explains a science concept (temperature) using everyday example of charging a cellphone.

Utterances 24-29 (combination of semantic wave and a flatline)

During utterance 24 the teacher introduces a new concept (conductor with relation to Ohm's law) which condenses many meanings, hence it has a SD score of 5 (Table 12 and Figure 16). Utterance 25 lowers the SD score to a 4 as the teacher scientifically unpacks the concept non-ohmic conductors by referring two variables (charge and temperature). Utterance 26 sees the lowering of SD score to a 1 as the teacher uses one everyday example of a bulb to illustrate what a non-ohmic conductor is. Utterance 27,28 and 29 increases the SD score to 3 as the teacher scientifically: identifies the second type of conductor-ohmic conductor (utterance 27); explains what a ohmic conductors are by referring to one variable – electricity (utterance 28); and names two examples of ohmic conductors- copper and nichrome wire (utterance 29).

Utterances 30-47 (combination of semantic waves and a flatline)

During utterance 30 the teacher hints towards a graph for ohmic and non ohmic conductors, which condenses many meanings, hence it has a SD score of 5 (Table 12 and Figure 16). Utterance 31 and 32 lower the SD score to 4 as the teacher scientifically explains: what an ohmic conductor is by considering two variables-current and voltage (utterance 31); using the graph the relationship between the two variables-current and voltage (utterance 32). Utterance 33 lowers the SD score to a 3 as the teacher explains a science concept by considering multiple science examples (copper, copper wire, nichrome wire). During utterance 34 the SD score is increases to a 5 as the teacher asks a question related to a graph of a non-ohmic conductor, which condenses many meanings. Utterance 35 and 36 lower the SD score to 4 as the teacher uses a graph: to describe scientifically the shape of a non-ohmic conductor (utterance 35); pointing at the graph inferring two variables, for a non- ohmic conductor and refers to a another variable -voltage (utterance 36). Utterances 37 sees the lowering of the SD score to 2 as the teacher uses everyday language explaining a procedure drawing on two parts (quantity and unit). Utterances 38,39,40,41 and 42 increase the SD score from a 2 to a 4. During those utterances the teacher scientifically unpacks the scientific concept of non-ohmic conductor by a number of means: describing it using five variables- Ohms' law, voltage, current and shape of the graph (utterance 38); asking a science question about the shape of the graph which infers two variables- voltage and current (utterance 39); refers to the graph to explain indirect proportionality referring to five variables- voltage, temperature, current, resistance, and flow of charge (utterance 40); explains by referring to a graph inferring to two variables (current of resistance) how conductors obey/disobey Ohms' law (utterance 41); explains its shape of a graph by considering three variables - force, movement of charge, resistance (utterance 42). Utterance 43 lowers the SD score to 2 as the teacher uses everyday example (a bulb) to explain a science concept of non-ohmic conductors. During utterance 44 the SD score is increased to 4 as the teacher names to two variables (current and voltage) needed to calculate resistance, leading to a word formula. Utterance 45 increase the SD score to 5 as the teacher condenses two variables (voltage and current) to form a word formula for resistance, which condenses many meanings. Utterances 46 and 47 lower the SD score to 3 as the teacher refers to resistance, using a graph, to explain a non ohmic conductor.

Analysis of experienced teacher's profile for lesson five

Table 13 below shows the coding description and subsequent SD coding score for each experienced teacher utterance of lesson five, which is based on the concept of power. The semantic density profile for this lesson, based on the SD coding score, is depicted in Figure 17. The profile is characterized by a strongly scientific approach with high semantic density waves (SD scores of 3 and more). There is later in the lesson one high semantic density reference with a SD score 5. Three times in the lesson the teacher draws on everyday language and examples to unpack dense concepts (SD score 1 and 2).

Table 12 : Coding description and Semantic density coding score for all utterances of lesson five electrical power for the experienced teacher.

Utterance	**Description of class interaction and subsequent coding choice**	**SD scale**
1. Today we are going to look at the topic of power.	Teacher introduces a new concept power which condenses many meanings.	**5**
2. Power is related to energy.	Teacher scientifically relates power to energy. Both concepts condense many meanings.	**5**

3. Power in general is the rate of transfer of energy.	Teacher defines scientifically what power is by referring to the rate of transfer of energy, which infers multiple variables.	**4**
4. Now this one is electrical power. What is electrical power?	Teacher considers by way of a question electrical power which by pointing at an example.	**4**
5. Power itself is the rate of doing work and electrical power is the rate of transfer of electrical energy.	Teacher explains scientifically what power is by referring to multiple parts (electrical power, rate of doing work and rate of transfer of electrical energy).	**4**
6. Because work is the transfer of energy from one form to another.	Teacher repeats scientifically the definition of work but considers one variable, energy transfer.	**3**
7. Therefore, when electrical energy is transferred to other forms for example the energy that goes to the bulb is transferred to light energy.	Teacher describes scientifically the types of energy conversion (one process with more than one form of energy) that are taking place in a bulb.	**4**
8. When electrical energy is moving along the conductor or electrical energy is used in different equipment we need that energy in different forms that we need.	Teacher considers uses of electrical energy by referring to a two parts, conductor and conversion of energy.	**4**
9. From the bulb we need light therefore electrical energy is transferred to light in the bulb.	Teacher refers scientifically to an example of energy transfer in a bulb. Teacher uses single variable (energy transfer which has more than one form of energy).	**4**
10. How about the oven. Cooking oven?	Teacher question refers to a single everyday example of an oven.	**1**
11. Electrical energy is transferred to heat energy.	Teacher describe scientifically the type of energy transfer, a single variable (two forms of energy), in an oven.	**4**
12. How about the microphone?	Teacher question refers to a single everyday example of a microphone.	**1**
13. Electrical energy is transferred to movement and to sound.	Teacher describe scientifically the type of energy transfer, a single variable (two forms of energy), in a microphone.	**4**

14. When we are talking about power here it is how fast the object for example the bulb, the oven or whatever is using electricity. How fast it changing the electrical energy into the desired kind of energy. It can be heat. light, sound, movement etcetera.	Teacher unpacks scientifically the concept “Power” referring to three variables (the rate of use of electricity, energy transfer, and the types of energy in everyday examples).	**4**
15. Therefore, electrical power can be calculated, can be measured and can be calculated. The unit of electrical power is?	Teacher uses everyday language to suggest that a formula (which contains multiple parts) can be used to calculate electrical power and that it has units too. Teacher considers two parts, units of power and formula for power.	**2**
16. Watts is the unit of electrical power.	Teacher introduces scientifically the unit of power watts, which condenses many meanings.	**5**
17. And to calculate the electrical power we use the formula which is the voltage multiplied by current.	Teacher condenses two variables, voltage and current, into a word formula for electrical power, which condenses many meanings.	**5**
18. Example an electrical kettle allows a current of five amperes when connected to a two hundred and thirty Volt mains. Now find its power.	Teacher refers scientifically to an example trying to unpack the word formula for power, which contains multiple parts.	**4**
19. The first thing you do is to write down the formula. The formula is always having a mark which is power equals to voltage times current. The answer will be one thousand one hundred and fifty Watts.	Teacher scientifically tries to unpack the formula by referring to a procedure and an example calculation.	**4**
20. Now, can you do this activity? Calculate the power of the bulb in this circuit.	Teacher considers an example calculation by referring to a bulb in a circuit and asks the learners to calculate the power.	**3**
21. The current is one point five and this one is six. The power is equal to voltage times current. Which is 6 multiplied by one point five. The answer is nine Watts.	Teacher scientifically applies the formula by referring to an example calculation.	**4**
22. Also know that one kilowatts is one thousand watts.	Teacher does a mathematical operation regarding conversion between metric units (kilowatts to watts).	**4**

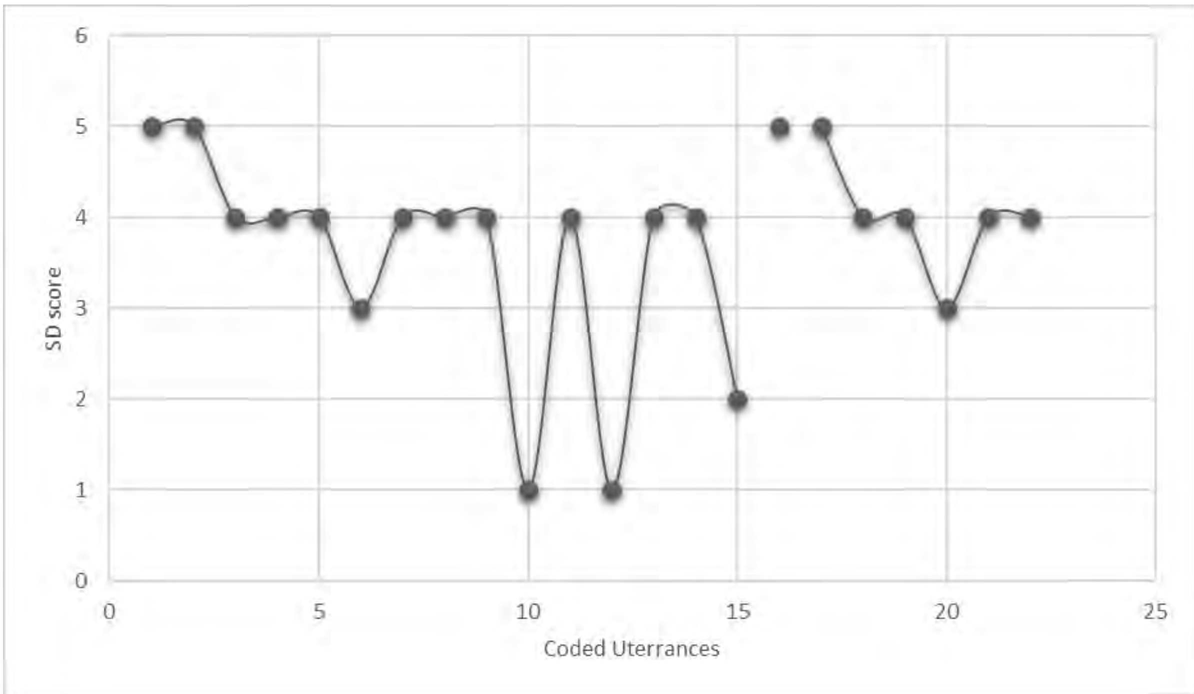


Figure 17: Semantic density profile for lesson five (experienced teacher)

Utterance 1 – 15 (wave)

At the start of the lesson the teacher introduces a new scientific concept of power, which condenses many meanings, hence it has a SD score of 5 (Table 13 and Figure 17). During utterance 2 the teacher scientifically relates power to energy. Both concepts (power and energy) condense many meanings hence utterance has a SD score of 5. Utterances 3,4 and 5 lower the SD score to a 4 as the teacher scientifically: defines power referring to rate of transfer- which infers multiple variables (utterance 3); poses a question about electrical power (utterance 4); and explains the concept of power referring to multiple variable- electrical power, rate of doing work, rate of transfer of electrical energy (utterance 5). Utterance 6 sees the lowering of SD score to 3 as the teacher scientifically defines work by referring to one variable (energy transfer). Utterances 7,8 and 9 increase the SD score to a 4 as the teacher scientifically: describes the energy transfers in a bulb (utterance 7); names the uses of electrical energy referring to two variables – conductor and conversion of energy (utterance 8); and refers to the energy transfers in a bulb (utterance 9). Utterance 10 sees the lowering of SD score to 2 as the teacher ask a question referring to a single everyday example of an oven. During utterance 11 the SD score increases to a 4 as the teacher scientifically describe the type of energy transfers in an oven. Utterance 12 sees the lowering of SD score to 2 as the teacher ask a question referring to a single everyday example of a microphone. Utterances 13 and 14 increases the SD score to 4 as the teacher scientifically: describes the energy transfers in a microphone (utterance 13); and refers to three variables- rate of use of electricity, energy transfer, the types of energy (utterance 14). Utterance 15 sees the lowering of SD score to a 32 as the teacher uses everyday language to suggest that a formula can be used to calculate electrical power and that it has units.

Utterance 16 (Single reference)

Utterance 16 has a SD score of 5 (Table 13 and Figure 17) as the teacher scientifically introduces the unit of power, which condenses many meanings.

Utterances 17 -22 (waves)

Utterance 17 has a SD scores of 5 (Table 13 and Figure 17) as the teacher condenses two variables (voltage and current) into a word formula for electrical power, which condenses many meanings. Utterances 18 and 19 see the lowering of SD score to a 4 as the teacher scientifically: refers to an example to unpack the formula for power (utterance 18); and refers to a procedure and an example calculation to unpack the formula for power (utterance 19). Utterance 20 lowers the SD score to 3 as the teacher refers to an example (bulb) and ask learners to calculate power. Utterances 21 and 22 increase the SD score to 4 as the teacher scientifically: applies the formula by referring to an example calculation (utterance 21); does a mathematical operation referring to conversion between metric units- kilometer to meters (utterance 22).

Analysis of experienced teacher's profile for lesson six

Table 14 below shows the coding description and subsequent SD coding score for each experienced teacher utterance of lesson six, which is based on the concept of electricity and safety issues. The semantic density profile for this lesson, based on the SD coding score, is depicted in Figure 18. At the beginning of the lesson there is one low semantic density reference (SD score 2), one high density reference (SD score 5) and a low flatline (SD score 2). Two times in the lesson the teacher draws on everyday examples to unpack dense concepts (SD score 1). Later in the lesson there are unpacking and repacking waves that remain at a high semantic density (SD score 3 and 4).

Table 14 : Coding description and Semantic density coding score for all utterances of lesson six for the experienced teacher.

Utterance	Description of class interaction and subsequent coding choice	SD scale
1. Today we are going to talk about the uses of electricity and safety issues.	Teacher introduces a science concept by drawing on two everyday concepts: uses of electricity and safety issues	**2**
2. Yesterday we talk about electrical power and electrical energy.	Teacher refers to previously learned concepts of power and electrical energy. Both concepts condense many meanings.	**5**
3. So, the uses of electricity are all known to us because the uses of electricity we have around us, at schools and also at homes.	Teacher unpacks the concept of uses of electricity pinpointing at multiple everyday examples of places where electricity is used	**2**
4. What do you use electricity for? For cooking, to operate our fans. There are so many uses if fans. To charge our cellphones. To give us light. To operate our machines such as photocopies, for heating. Heat we can use it on electrical irons. Those are the common uses of electricity that we have at home.	Teacher unpacks the concept of uses of electricity using everyday language and multiple everyday examples	**2**
5. But we need to conserve electricity isn't? Why is it important to conserve electricity?	Teacher introduces another science concept by drawing on two everyday concepts: electricity and its conservation.	**2**
6. Conserving electricity means saving units.	Teachers explains scientifically the meaning of the concept conservation of electricity by considering a single variable (saving units).	**3**
7. Why do we need to save units? To reduce the cost so that we save money.	Teachers further unpacks the concept of electricity conservation using everyday language and mentions two components: reducing cost and saving money.	**2**
8. To meet everyone's demand. To overuse electricity, we might not meet the demand of everyone in town. Production is	Teachers continues to unpack the concept using everyday language by providing multiple reasons why electricity must be conserved.	**2**

limited and therefore we need to use electricity wisely so that everybody will have some units to use.		
9. Now electricity can be dangerous.	Teacher introduces another science concept by drawing on two everyday concepts: electricity and its danger	**2**
10. Have you ever heard of anything dangerous caused by electricity?	Teacher starts to unpack the danger of electricity by using everyday language to ask a single component question.	**1**
11. The electric shock and you can even die.	Teacher continues to unpack the dangers of electricity using everyday language, mentioning two examples: shock and death	**2**
12. And therefore we need to consider some safety precautions whenever we are working with electricity. Safety precautions are- there are some things that we are told at home normally when we are working with electricity.	Teacher introduces another science concept by drawing on two everyday concepts: electricity and precautions in its use	**2**
13. There are things that we are cautioned not to do, like what?	Teacher starts to unpack the precautions with electricity by using everyday language to ask a single component question.	**1**
14. Unplug the kettle when you fill in the water. And you must not hold electric appliances with wet hands, why?	Teachers mentions two everyday examples of precautionary measures and hints, via question, towards a scientific concept of electric shock.	**2**
15. If your hands are wet. Water may contain some charges. And you know electricity can be carried by the charges. Therefore, if your hands are wet. The electricity will pass through this water or the charges in water will carry electrical charges and then it will come into your body and you will be shocked.	Teacher unpacks scientifically the concept of electric shock by referring to multiple components/ variables: water, charge, electricity passing through, movement of charge	**4**
16. Blood in your body contain charges and this charges can let electricity to pass through the body and you get a shock. And what else?	Teacher further unpacks scientifically the concept of electric chock by referring to multiple components/ variables: blood, charge, electricity passing through,	**4**

17. Do not overload the socket. Do not use damaged cables, do not poke thinks inside socket. For example, if the insulations are teared. The electricity will pass through which can allow you to get shocked. Do not use electric appliances in the bathroom, do not fix electrical appliances while on power.	Teacher unpacks the concept of electrical shock by drawing on multiple everyday examples: socket, damaged cables, insulations, appliances in bathrooms, fixing appliances.	**2**
18. Discuss the importance of a fuse, earth breaker and earth wire We have a few things that we use to reduce the danger of electricity. Electricity can be made safer by a fuse, using a fuse, earth breaker and earth wire and insulation.	Teacher further unpacks scientifically the concept of reducing the danger of electricity by referring to multiple parts: fuse, earth breaker, earth wire, insulation	**4**
19. The fuse is a thin wire which melts if too much current goes through it. It is connected between electric supplier to the machine that uses the electricity. The fuse will melt when the amount of electricity needed by the machine is exceeded.	Teacher explains scientifically the concept and use of a fuse in electrical safety by drawing on two concepts: too much current, melting. Teacher considers the concept of fuse and explains in general how it works.	**4**
20. For example, the radio is only using five volts, now the electricity from the supply says six volts if it passes through the circuit breaker, it will melt because it does not allow too much to go through, otherwise the appliance will break or will explode, to avoid that it will melt and instead of you buying a new radio. You will only replace the fuse which is cheaper.	Teacher further explains scientifically electrical safety using multiple variables: current, voltage and circuit breaker.	**4**
21.You can use the circuit breaker. This circuit breaker it traps off the main switch. When something wrong is connected in the circuit. This circuit breaker it traps off the main switch. When something wrong is connected in the circuit.	Teacher unpacks scientifically the concept of reducing the danger of electricity by drawing on a multiple variables/parts: circuit breaker, main switch, wrong connection.	**4**

22. And the earth wire transfers the current to the earth when short circuit occurs.	Teacher unpacks scientifically the concept of reducing the danger of electricity by drawing on a multiple variables/parts: earth wires, current, earth and circuit.	**4**
23. The plastic insulation it covers electrical wire.	Teacher unpacks the dangers of electricity by mentioning everyday examples: plastic insulation and electric wire.	**2**
24. The earth wire is one of the three wires in the three pin plug which directs the current to the earth when a short circuit occurs to avoid explosion and shocks	Teacher unpacks scientifically the dangers of electricity by referring to multiple parts/variables: earth wire, plug, current, short circuit, explosion, shock.	**4**
25. The earth wire is green or yellow or green-yellow. There is a live wire it is brown in colour the neutral is blue in colour.	Teacher unpacks dangers of electricity by referring to multiple parts: earth wire (and its colour) and live wire (and its colour) life wire, which condenses many meanings.	**4**
26. We have been talking about a short circuit. How does a short circuit occur? It occurs when a wrong wire is connected across two points in a circuit. The low resistance causes more current to pass through	Teacher unpacks dangers of electricity by referring to multiple parts/ variables: short circuit, current, resistance	**4**

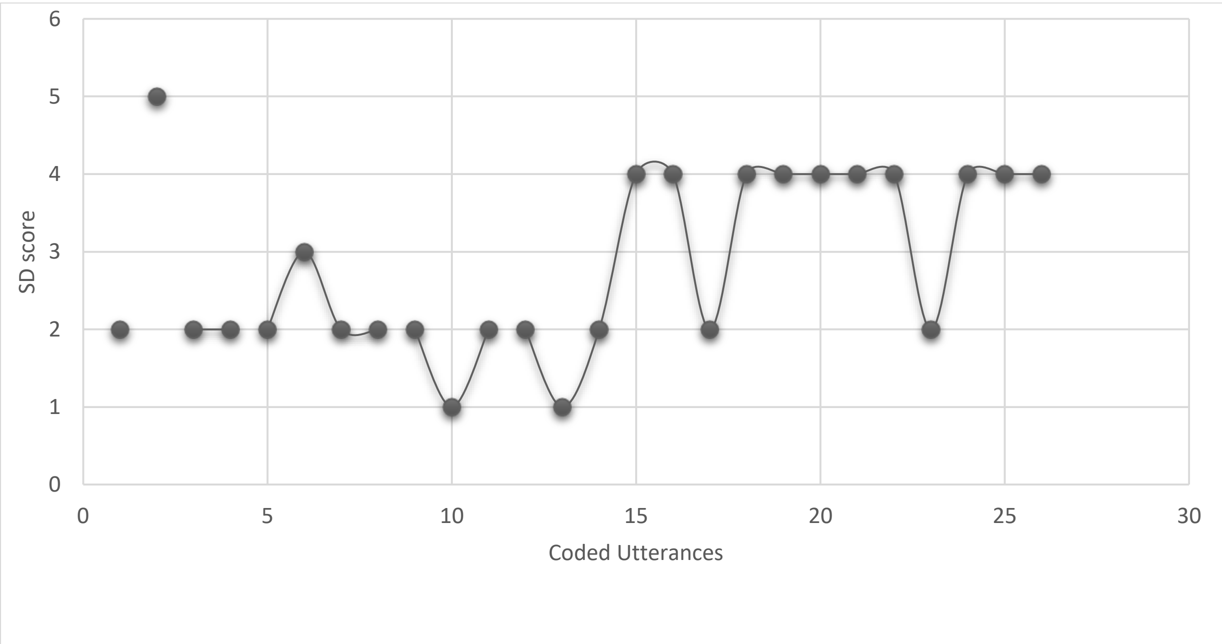


Figure 18: Semantic density profile for lesson six (Experienced teacher).

Utterance 1 (single reference)

At the start of the lesson the teacher introduces a new scientific concept by drawing on two everyday concepts (uses of electricity and safety) hence it has a SD score of 2 (Table 14 and Figure 18).

Utterance 2 (Single reference)

Utterance 2 also has a SD score of 5 (Table 14 and Figure 18) as the teacher refers to a previously learned concept and electrical energy. Both concepts condense many meanings.

Utterances 3-4 (flatline)

Utterances 3 and 4 lower the SD score to a 2 (Table 14 and Figure 18) as the teacher unpacks the concept of uses of electricity: referring to multiple everyday examples of places where electricity is used (utterance 3); and mentions using everyday language multiple everyday examples (utterance 4).

Utterances 5-8 (wave)

Utterance 5 has a SD score of 2 (Table 14 and Figure 18) as the teacher introduces another science concept using two everyday concepts (electricity and conservation). During utterance 6 the SD score increases to 3 as the teacher scientifically explains the meaning of conservation of electricity by considering a single variable (saving units). Utterances 7 and 8 lower the SD score to 2 as the teacher unpacks the concept of conservation of electricity using everyday language by: mentioning two components- reducing cost and saving money (utterance 7); and providing multiple reasons why electricity must be conserved (utterance 8).

Utterance 9-11 (wave)

Utterance 9 has a SD score of 2 (Table 14 and Figure 18) as the teacher introduces another science concept using two everyday concepts (electricity and danger). Utterances 10 lowers the SD score to 1 as the teacher unpacks by using everyday language the concept of dangers of electricity considering a single component question. During utterance 11 the SD score increases to 2 as the teacher uses everyday language to unpack the dangers of electricity considering two examples (shock and death).

Utterance 12-26 (waves)

Utterance 12 has a SD score of 2 (Table 14 and Figure 18) as the teacher introduces another science concept using two everyday concepts (electricity and precautions in its use). Utterance 13 lowers the SD score to 1 as the teacher unpacks by, using everyday language, the concept of precautions with electricity considering a single component question. During utterances 14 the SD score increases to 2 as the teacher uses everyday examples of precautionary measures. Utterances 15 and 16 increase the SD score to 4. During those utterances the teacher scientifically unpacks the concept of electric shock referring to multiple components- water, charge, electricity passing through, movement and blood. Utterance 17 sees the lowering of SD score to 2 as the teacher further unpacks the concept of electrical shock by considering multiple everyday examples (socket, damaged cables, insulations, insulations, appliances in the bathroom and fixing the appliances). Utterances 18,19,20,21 and 22 increase the SD score to 4. During those utterance the teacher scientifically unpacks the concept of reducing the dangers of electricity by a number of means : referring to multiple parts- fuse earth wire, earth breaker and insulation (utterance 18); the concept and use of a fuse in electrical safety drawing on two concepts- too much current and melting (utterance 19); explains electrical safety using multiple variables- current, voltage and circuit breaker (utterance 20); unpacks the dangers of reducing of dangers of electricity by drawing on multiple parts- earth wires, circuit breaker main switch and wrong connections (utterance 21); by drawing on a multiple variables/parts- : earth wires, current, earth and circuit (utterance 22). Utterance 23 sees the lowering of SD score to a 2 as the teacher unpacks the danger of electricity by considering everyday examples (plastic insulation and electric wire). Utterances 24, 25 and 26 increase the SD score to 4. During those utterances the teacher scientifically unpacks, considering multiple parts, the concept of dangers of electricity by referring to: earth wire, plug, current, short circuit, explosion and shock (utterance 24); earth wire and its colour, live wire and its colour, life wire and its colour (utterance 25); short circuit, current and resistance (utterance 26).

Analysis of experienced teacher's profile for lesson seven

Table 15 below outlines the coding description and subsequent SD coding score for each utterance of the experienced teacher in lesson seven, which is based on the concept of charge. The semantic density profile for this lesson, based on the SD coding score, is depicted in Figure 19. Overall, most of the lesson consisted of the teacher unpacking and repacking dense scientific concepts (SD score of 5) using both less condensed, everyday examples and explanations (SD score of 1 and 2) as well as more condensed scientific explanations (SD score of 3 and 4).

Table 15 : Coding description and Semantic density coding score for all utterances of lesson seven on charges for the experienced teacher.

Utterance section	**Description of class interaction and subsequent coding choice**	**SD score**
1. Good morning class today we shall learn about the charges.	Teacher introduces the scientific term ‘charge’, which condenses many meanings.	**5**
2. And we have two types of charges, what are they? We have two types of charges? Positive charges and negative charges.	Teacher asks and then explains scientifically that charge can be considered in two distinct forms (positive and negative).	**4**
3. And how do charges form? For something to say it is charged it is when it does what? It is when it loses and gains electrons.	Teacher asks about how charges are formed and then explains – referring to two scientific processes (losing and gaining electrons).	**4**
4. Okay then we have two types of charges, positive charge and negative charge.	Teacher repeats scientific information on two distinct forms of charge (positive and negative).	**4**
5. So, for something to form a charge it is when material have lost or it gained an electron and form the anion or? Cation the charge.	Teacher explains scientifically charge formation in terms of two distinct parts (cations and anions)	**4**
6. If the element or atom or the material lost an electron - it forms which one? Is it positive or negative? If it loses an electron? It will form a positive charge.	Teacher asks and explains scientifically one process (losing an electron).	**3**
7. And if it gains electrons? It forms a negative charge.	Teacher asks and explains scientifically one process (gaining an electron).	**3**
8. A negative electron I mean negative charge, this charge especially on the material for example the ruler the plastic ruler or the plastic the pen pencil or the cloth when they are rubbed against each other than it will form the charge and you used to see the light when it is dark, on the sheets	Teacher continues explaining using everyday language and multiple everyday examples (ruler, pen, cloth, rubbing, charge, light, dark, etc.).	**2**

or the clothes. It gives something like a light.		
9. So those ones are the proves that shows that there are charges or there are materials that are charged.	Teacher repeats an example in everyday language implying multiple examples (materials).	**2**
10.When the charges are the same for example positive and positive or negative and negative they repel each other …	Teacher explains scientifically the process of repulsion based on one concept (likeness of charge).	**3**
11. And when they are different like negative and negative positive and positive they attract each other.	Teacher explains scientifically the process of attraction based on one concept (opposite charges).	**3**
12. Now, we have the charges are the ones that make us to have electricity.	Teacher explains that charge is responsible for providing electricity, which is an everyday example.	**1**
13. We have two types of electricity. What are they? There are two types of electricity. You did this in grade nine right?	Still using the everyday example of electricity, the teacher indicates there are two types of electricity.	**2**
14. The two types of electricity. Static electricity and current electricity. What is the difference between this two?	Teacher explains scientifically that there are two types of electricity (static and current).	**4**
15. Static electricity is electricity which does not move. Which means there are no flow of charges. The charges are not flowing along the conductor …	Teachers explains scientifically static electricity using a single process (lack of flow of charge in a conductor).	**3**
16. And current electricity is when the charges are moving along the conductor.	Teacher explains scientifically current electricity using a single process (flow of charge).	**3**
17. Static electricity is produced when non-conductors are rubbed together it can be continuously generated when the objects are rubbed against each other …	Teachers explains scientifically how static electricity is produced in terms of a single process (non-conductors rubbing).	**3**
18. And current electricity the flow of charges per unit of time.	Techer defines scientifically current electricity using two variables (flow of charge and time).	**4**
19. And the current flows through the conductor such as metal, graphite and a solution.	Teacher names scientific examples of materials through which electricity flows (graphite, solution).	**3**
20. We have some materials that current can flow or whereby charges can flow and some	Teacher continues to explain scientifically that different materials can have a different effect on flow of charge.	**3**

materials whereby current cannot flow.		
21. The materials that allow charges to flow are for example metals and we call them the good conductors of electricity.	Teacher explains scientifically what good conductors are using one process (flow of charge), and what they are made of using one example (metals).	**3**
22. And there are some materials that do not allow the charges to flow and they are called insulators or non-conductors of electricity.	Teacher explains scientifically what non-conductors are using one process (no flow of charge).	**3**
23. And examples of non-conductors of electricity are the materials that do not allow electricity to flow through. They are plastic, wood, papers, etcetera.	Teacher names everyday examples of non-conductors (plastic, wood, paper).	**1**

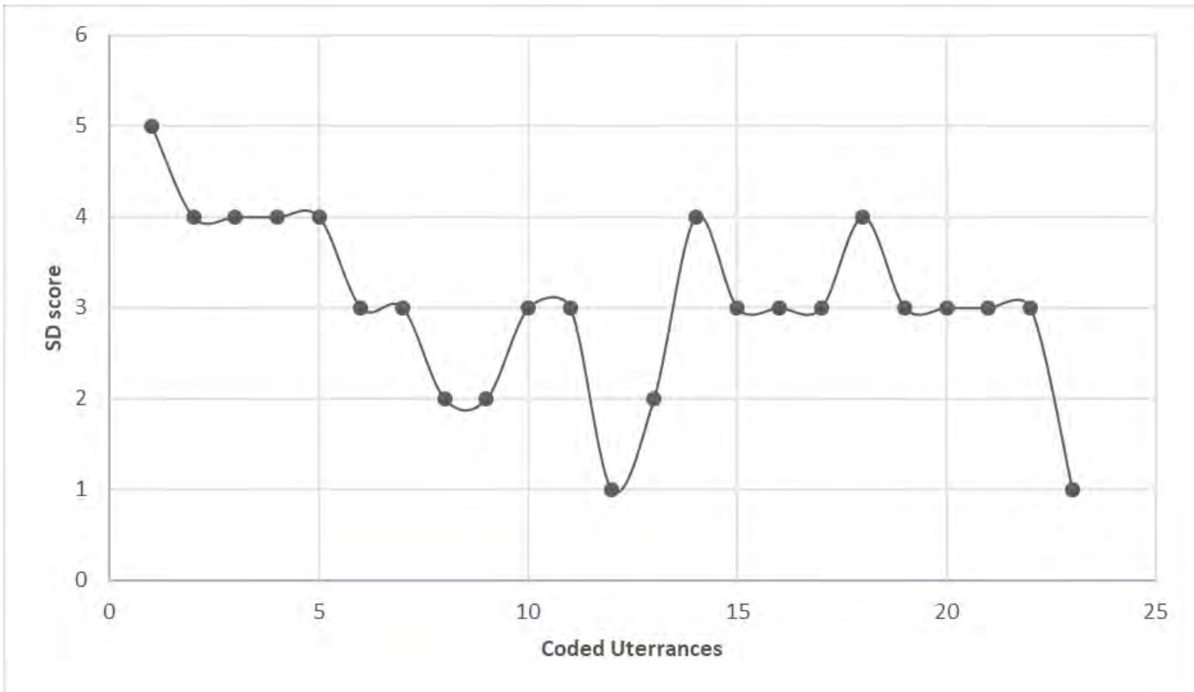


Figure 19: Semantic density profile for lesson seven (Experienced teacher). Utterances 1-23 (semantic waves)

At the start of this lesson the teacher introduces a new scientific concept of charges (Table 15 and Figure 13), which condenses many meanings and therefore has a high SD score of a 5. Utterance 2 lowers the SD score to a 4 as the teacher scientifically unpacks the concept by referring to its two distinct forms (positive and negative charges). Utterances 3 and 4 keep the of SD score at a 4 as the teacher unpacks the concept of charge by referring to two processes (loosing and gaining) and two distinct forms (positive and negative charges), respectively. In utterance 5 the teacher scientifically explains the formation of charge by considering two distinct parts (cations and anions). This further keeps the SD score at a 4. Utterance 6 lowers the SD score to a 3 as the teacher asks and explains a single process (loosing of electrons).With Utterances 7 the SD score remains at a 3 as the teacher scientifically unpacks the concept of charge referring to one process (gaining an electron). Utterances 8 and 9 further lower the SD score from 3 to a 2 as the teacher explains the concept using everyday language and multiple everyday examples (ruler, pen, cloth, rubbing, charge, light, dark). During utterances 10 the teacher scientifically explains the process of repulsion by referring to one concept (likeness of charge) and while in utterance 11 the teacher also explains scientifically the process of attraction by considering one concept (opposite charges). Both utterances 10 and 11 increase the SD score to a 3. In utterance 12 the teacher uses everyday language and everyday example about the uses of charges, which lowers the SD score to a 1. During utterance 13 the SD score is increased to a 2 as the teacher refers to everyday examples of electricity and indicates that there are two types of electricity. In utterance 14 the teacher explains scientifically that there are two types of electricity (static and current), this further increases the SD score to a 4. Utterance 15 sees the SD score lowered again to a 3, whereby the teacher scientifically explains what static electricity is by referring to a single process (lack of charge in a conductor). Teacher scientifically explains, during utterance 16, current electricity by referring to a single process (flow of charge). Similarly, during utterance 17 the teacher scientifically explains static electricity by also referring to a single process (non-conductors rubbing). Both utterances 16 and 17 keep the SD score at a 3. Utterance 18 sees the SD score increasing to a 4 as the teacher uses two variables (flow of charge and time) to scientifically define current electricity. Utterance 19, 20,21 and 22 keep the SD score at a 3 as the teacher names scientific examples of materials –graphite and solution through which electricity flow (utterance 19); teacher explains scientifically that different materials can have different effect on the flow of charge (utterance 20); teacher refers to a single process of flow of charge and one example (metals) to explain what non-conductors are- (utterance 21); teacher scientifically explains what non-conductors are by referring to one process (flow of charge) in utterance 22. The concluding utterance 23 lowers the SD score to a 1 as the teacher names everyday examples of non-conductors (plastic, wood and paper).

Appendix C : Lexical density coding and calculations for utterances of lesson two to seven (Novice teacher)

Lexical density coding and calculations for utterances of lesson two on voltage by novice teacher.

Utterance section	Coding Notes	Number of content words	Total words	LD (%)
1."Class what is current? Yesterday we looked at current. What is current?"	**Coded** Science concepts	**3**	**12**	**25.0**
2."Current is the movement of charge along a conductor in a circuit".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**5**	**10**	**50.0**
3."Today we shall look at voltage, also known as potential difference".	**Coded** Science concepts	**3**	**11**	**27.3**
4. "Voltage is electric potential difference that exist between two points in a circuit. Electrons flow is a circuit and when you consider the amount of electrons at any two points in the circuit you will discover that they are not equal. It is because of that difference that we have voltage which is also called potential difference".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects/concepts	**17**	**56**	**30.4**
5. "Also when you consider the terminals of a cell. How many terminals do we have? Name them? Positive and negative terminal, they are two".	**Coded** Numbers in words quantifying science concepts/objects Words indicating categories of science objects/concepts.	**7**	**23**	**30.4**
6. "The terminals also have potential difference. It is that potential difference that are forcing the charges to move from negative to positive terminal. They are gaining a force to move from one terminal to another. They call that force an electromotive force".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**18**	**41**	**43.9**
7. "How do we measure voltage and what is the unit of voltage?"	**Coded** Science concepts Words frequently used in science indicating unit and quantity.	**3**	**12**	**25.0**

8. "Voltage is measured with a voltmeter and its unit is Volt, capital V. The voltmeter is placed across the resistor".	**Coded** Science concepts Units of science concepts/ variables(in words and symbols) Words indicating categories of science objects/concepts. Words frequently used in science indicating unit and quantity.	**7**	**19**	**36.8**
9. "To calculate the voltage across a bulb or a resistor we use the formula V equals I times R".	**Coded** Science concepts Words indicating categories of science objects. Formula in words. Words frequently used in science indicating mathematical operation. (including the word formula). "	**10**	**17**	**58.8**
10. "I stand for current and R stands for resistance".	**Coded** Science concepts (in words and symbols).	**4**	**9**	**44.4**
11. " Here if the current is 3 amperes and the resistance is 2 ohms the voltage will be 6 volts".	**Coded** Science concepts Numbers quantifying science concepts. Units of science concepts/ variables	**9**	**19**	**47.4**
12."Next, we look at voltage in series circuit and voltage in parallel circuit. The voltage in series and in parallel is not the same, it differs".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects/concepts.	**11**	**26**	**42.3**
13. "If you have series circuit like this one. You can see that the components, which are the three bulbs, are connected in a straight line".	**Coded** Words indicating categories of science objects.	**3**	**24**	**12.5**
14. "The voltage become less as it is consumed by the components, the bulbs".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**3**	**13**	**23.1**
15."In this case the voltage that is supplied by the battery equals the sum of the voltage of the three bulbs".	**Coded** Science concepts Words indicating categories of science objects. Words frequently used in science indicating mathematical operation.	**6**	**21**	**28.6**

16."If you take V1 plus V2 plus V3 it will give you the total Vt. That is the formula for the resistance in series".	**Coded** Science concepts Words indicating categories of science objects. Formula in words. Words frequently used in science indicating mathematical operation. (including the word formula).	**10**	**24**	**41.7**
17. Here you can see that V1 is 1,5 Volts, V2 is 1.5 Volts and V3 is 2 Volts. What is the total voltage? It is 4 volts.	**Coded** Science concepts Numbers in words quantifying science concepts/objects Units of science concepts/ variables Words frequently used in science indicating mathematical operation.	**13**	**27**	**48.1**
18. "In parallel circuits the bulbs are not connected in one line. They are connected in branches".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects	**6**	**16**	**37.5**
19. "In parallel the voltage will be the same for each component. This means that the voltage in this bulb is the same as the voltage in that bulb and also the same in this one which is the same as the voltage in the cell or the battery".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**13**	**48**	**27.1**
20." Now, please try to do the four examples in the worksheet. Once again do not forget to indicate the units for each step".	**Coded** Words such as units , frequently used in science	**1**	**23**	**4.3**
21."Your answers are correct but what is your conclusions for bulbs in series and bulbs in parallel about the total voltage?"	**Coded** Science concepts Words indicating categories of science objects. Words frequently used in science indicating mathematical operation.	**6**	**21**	**36.1**
22. "The bulb in series the voltages add up to give you the total voltage of the battery while in parallel the voltage in each resistor is the same as the one in the battery or cell".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects. Words frequently used in science indicating mathematical operation	**13**	**36**	**36.1**
23. "Our next topic will be resistance".	**Coded** Science concepts	**1**	**6**	**16.7**

Lexical density coding and calculations for utterances of lesson three on electric resistance by a novice teacher.

Utterance section	Coding Notes	Number of content words	Total words	LD (%)
1. "Yesterday we talked about voltage. Do you remember what voltage is?"	**Coded** Science concepts .	**2**	**11**	**18.2**
2. "We said that voltage is the electric potential difference that exist between two points in a circuit. What is the unit of voltage? The unit is volts".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words frequently used in science to referring to units. Words indicating categories of science objects/concepts.	**11**	**27**	**40.7**
3. "Today we shall talk about resistance. We have roughly mentioned resistance before? Can anyone recall what it is?"	**Coded** Science concepts	**2**	**18**	**11.1**
4. "When we say you resist to move, what does that mean? Yes, it means refuse to move".	**Coded** None	**0**	**17**	**0**
5. "Resistance in Physical Science means opposition to flow of charge or current. Resistance is represented by a capital letter R and it is measured in ohms. The unit for resistance is ohms. Like current and voltage, we also use a formula to calculate the resistance. Anyone who can give us the formula?"	**Coded** Science concepts(in words and symbols) Words use frequently in science referring to specific field of science Words related to a definition of a science concept and shaping a scientific process. Units of science variables/concepts Words frequently used in science to referring to units. Words frequently used in science indicating mathematical operation. (including the word formula).	**18**	**53**	**34.0**
6. "The formula is R equals to V divided by I".	**Coded** Formula in words. Words frequently used in science indicating mathematical operation. (including the word formula).	**5**	10	50.0
7. "V stands for voltage and I for current".	**Coded** Science concepts (words and symbols).	**4**	**8**	**50.0**

8."For example, in this circuit the voltage is seven volts and the current is two amperes. The resistance will be R equals to seven volts divided by two amperes. The answer will be three point five volts, I mean ohms".	**Coded** Science concepts (in words and symbols). Numbers in words quantifying science concepts/objects Units of science concepts/ variables Words indicating categories of science objects. Words frequently used in science indicating mathematical operation.	**20**	**40**	**50.0**
9. "The total Resistance differ between a parallel and series circuit. The procedure to get the total resistance in series circuit is different from the parallel one".	**Coded** Science concepts (in words and symbols). Words indicating categories of science objects. . Words frequently used in science indicating mathematical operation.	**10**	**25**	**40.0**
10. "Let's look at resistance in series. Here you are given the total current in the circuit and the voltage in the circuit? What will be the total resistance?"	**Coded** Science concepts Words frequently used in science indicating mathematical operation. Words indicating categories of science objects.	**9**	**28**	**32.1**
11. "The voltage here is 6V and the total current is 3A. The total resistance will be R_T equals to 6 volt divided by 3 amperes and the answer is 2 ohms. And do not forget to write the units as you proceed doing the calculations".	**Coded** Science concepts(in words and symbols) Numbers quantifying science concepts/objects Units of science concepts/ variables Words frequently used in science indicating mathematical operation. Variables frequently used in science..	**16**	**45**	**35.6**
12. "If you have three resistors to get the total resistance you add the individual resistance. The total resistance here will be how much?"	**Coded** Science concepts Words frequently used in science indicating mathematical operation. Words indicating categories of science objects..	**7**	**23**	**30.4**
13. "The total is R1 plus R2 plus R3 which is 2 ohms plus 3 ohms plus 1 ohms which is 6 ohms".	**Coded** Numbers quantifying science concepts Words frequently used in science indicating mathematical operation. Units of science concepts/ variables Formula in words.	**16**	**22**	**72.7**
14." Let's now look at the parallel circuit".	**Coded** Words indicating categories of science objects. .	**2**	**7**	**28.6**

15."The total resistance in this parallel circuit will be one over R T equals to one over R1 plus, one over R2 plus one over R1 plus, $(1/R_T = 1/R1+1/R2+1/R3)$".	**Coded** Numbers quantifying science concepts Formula in words. Numbers quantifying science concepts Words frequently used in science indicating mathematical operation.	**20**	**26**	**76.9**
16. "This will be $1/R_T$ equals ¼ + ¼+ ½ and if we change them into decimals they will become 1/ Rt= 0.25 ohms + 0.25 ohms + 0.5 ohms which is 1/Rt equals 1 ohms. To remove the one on the left side you write Rt = 1/1 . the answer will be 1 ohms".	**Coded** Numbers quantifying science concepts Words frequently used in science indicating mathematical operation. Units of science concepts/ variables Mathematical operations.	**41**	**68**	**60.3**
17. "Therefore, in parallel circuits the total resistance will be always be smaller than any of the resistance in the branches".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects. Words indicating laws in physics/science Words frequently used in science indicating mathematical operation.	**7**	**20**	**35.0**
18. "Can you do the rest of the calculations for resistance exercise and like I said. Do not forget to indicate the units when you do the calculations all the time".	**Coded** Science concepts Words frequently used in science to referring to units.	**2**	**30**	**6.7**
19." Now that we have done the calculations what do you conclude about the resistance in the two types of circuits?"	**Coded** Science concepts Words indicating categories of science objects.	**2**	20	10.0
20. "The total resistance in series circuit equals the sum of individual resistance in the resistors while in parallel circuit the total resistance is in not equal to the sum of resistors".	**Coded** Science concepts Words frequently used in science indicating mathematical operation. Words indicating categories of science objects.	**15**	**31**	**48.4**
21. "Tomorrow we shall talk about different factors that affect resistance".	**Coded** Science concepts Words indicating categories of science objects.	**2**	**10**	**20.0**

Lexical density coding and calculations for utterances of lesson four on factors affecting resistance by a novice teacher.

Utterance section	Coding Notes	Number of content words	Total words	LD (%)
1. “Yesterday we talked about resistance”.	**Coded** Science concepts	**1**	**5**	**20.0**
2. “We said resistance is the opposition of flow of charge in a circuit. We also said that resistance in parallel is different from the one in series”.	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	**7**	26	26.9
3. “Now, we are going to talk about different factors that affect resistance”.	**Coded** Science concepts Words indicating categories of science concepts.	**2**	12	16.7
4. “We have five such factors. They are four namely, temperature, the type of material, the length of the wire and the diameter of the wire”.	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words indicating categories of science objects/concepts.	**9**	**25**	**40.0**
5. “Increase in temperature increases resistance. Why is it so?”	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	**4**	**9**	**44.4**
6. “Because heat in the wire causes the atoms to collide with electrons and therefore the movement of electrons is limited”.	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**7**	**20**	**35.0**
7. “When it comes to the type of material some material allows electrons to move freely while some material will not. Those material that allow free movement of electrons have less resistance and they are called good conductors of electricity. Those that makes electron move difficult in them are having high resistance. They are not good conductors of electricity”.	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**18**	**58**	**31.0**
8. “Examples of good conductors of electricity are copper and silver. The electrons move freely”.	**Coded** Science concepts	**6**	**14**	**42.3**

	Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.			
9. "And Examples of none-conductors of electricity will be glass and plastics. Electrons do not flow through them	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**6**	**17**	**35.3**
10. Let's look at the length of the wire. How does it affect resistance?"	**Coded** Science concepts Words indicating categories of science objects/concepts.	**3**	**13**	**23.1**
11. "If the wire is longer the more resistance is more also in the wire. Why is it so?"	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**6**	**18**	**33.3**
12."Because if the wire is longer the electrons are traveling a longer distance as a result more collisions will take place and will the resistance be high".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**9**	**25**	**36.0**
13. "What do you think about the diameter or the width of the wire? If the diameter is bigger the resistance will decrease? Why is it so?"	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**7**	**26**	**26.9**
14. "Because the space through which the electrons move is big. There is space to move freely with less collision. Therefore, resistance is low".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**6**	**23**	**26.1**
15. "What is direct proportionality and indirect proportionality?	**Coded** Words frequently used in science for mathematical ratio/operations.	**4**	**7**	**57.1**
16. "If for example the temperature in the resistance increases the resistance will also increase. This means that temperature is directly proportional to the resistance".	**Coded** Science concepts Words frequently used in science for mathematical ratio/operations. Words related to a definition of a science concept and shaping a scientific process.	**9**	**24**	**37.5**

17. "You can see from this graph that the line is straight up".	**Coded** Words frequently used in science indicating mathematical operation. (including the word graph).	**1**	**12**	**8.3**
18. "And if the diameter of the conductor decrease the resistance will increase. This is indirectly proportional".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects/concepts.	**7**	**16**	**43.8**
19. "You can see that that graph is curving here".	**Coded** Words frequently used in science for mathematical ratio/operations..	**1**	**9**	**11.1**

Lexical density coding and calculations for utterances of lesson five on electrical power by a novice teacher.

Utterance section	Coding Notes	Number of content words	Total words	LD (%)
1."Yesterday we talked about factors that affect resistance. Can you name them?"	**Coded** Science concepts Words indicating categories of science objects/concepts.	**2**	**12**	**16.7**
2. "The temperature, diameter of conductor, length of a conductor".	**Coded** Science concepts Words indicating categories of science objects/concepts.	**5**	**8**	**62.5**
3. "Today's topic is about electrical power. What do you think is electrical power?"	**Coded** Science concepts	**4**	13	30.8
4. "Electrical power is related to electrical energy. It is the rate of transfer of electrical energy".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	**8**	**16**	**50.0**
5. "When we talk about electric energy we talk about the transfer of energy in different forms".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process	**4**	**16**	**25.0**

6. "For example, the battery in a circuit provides the? …. to light a bulb. The energy. Chemical energy is transferred to light. Or the stove gets hot because the electrical energy is transferred to heat energy".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**15**	**33**	**45.5**
7. " When we refer to a vehicle. What type of energy transfer is taking place? It is chemical energy the fuel that is converted into kinetic or movement energy".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	**7**	**27**	**25.9**
8. "Now electrical power will tell us how fast or slow that energy is converted. In other words, the conversion of energy for a given time. We can say per minute, per hour, per second, per month and so on".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words frequently used in science indicating mathematical operation.	**17**	**39**	**43.6**
9. "We need two things to be able to calculate electrical power in a circuit. let's look at this circuit we are given the voltage and the current. Those are the two things we need to calculate the electrical power".	**Coded** Science concepts Words indicating categories of science objects Words frequently used in science indicating mathematical operation. Variables frequently used in science.	**10**	**39**	**25.6**
10. "The formula for electrical power is P Equals V times I".	**Coded** Science concepts Formula in words and symbols.Words frequently used in science indicating mathematical operation. (including the word formula).	**8**	**11**	**72.7**
11. "If this current here is two amperes and the voltage is three volts the power will be three volts times two ampere. This will give us six watts".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Units of science concepts/ variables Words indicating laws in physics/science Words frequently used in science indicating mathematical operation.	**14**	**28**	**50.0**
12. "You can also use the formula to get the current by dividing power by voltage".	**Coded** Formula in words. Words frequently used in science indicating mathematical operation. (including the word formula).	**5**	**14**	**35.7**
13. "If the power is twelve watts and the if the current is six amperes your voltage will be two volts".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Units of science concepts/ variables	**9**	**20**	**45.0**

14. "What about current? It will be power divided by voltage".	**Coded** Science concepts Formula in words. Words frequently used in science indicating mathematical operation.	**4**	**10**	**40.0**
15. "For example here if the power is 8 watts and the voltage is 4 volts the current will be 2 amperes".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Units of science concepts/ variables	**9**	**21**	**42.9**
16. "You can see that I am writing the units in every step".	**Coded** None	**0**	**12**	**0.00**
17. "Try the next three examples to calculate the electric power, voltage and current".	**Coded** Science concepts Words frequently used in science indicating mathematical operation.	**5**	**13**	**38.5**
18. "Why did this person not get the maximum marks? Yes, he did not indicate the units in the second step".	**Coded** None	**0**	**20**	**0.00**

Lexical density coding and calculations for utterances of lesson six on uses and dangers of electricity by a novice teacher.

Utterance section	**Coding Notes**	**Number of content words**	**Total words**	**LD (%)**
1."Electricity is a wonderful thing. Why am I saying so? Because we benefit a lot from electricity".	**Coded** Science concept	**2**	**15**	**13.3**
2. "We use electricity in our houses, schools, shops, hospitals, cars and many other places".	**Coded** Science concept	**1**	14	7.1
3. "When we use it can cause problems to all us. It can be dangerous too. What dangers does electricity have?"	**Coded** Science concept	**1**	20	5.0
4. "If electricity is it not handled very well it can burn buildings and if there are people in the buildings they will die".	**Coded** Science concept	**1**	**23**	**4.4**

5. "Therefore we must be very careful when we are dealing with electricity. We need to take some precautions".	**Coded** Science concept	**1**	**18**	**5.6**
6. "Electricity can cause shock and death".	**Coded** Science concept	**1**	**6**	**1.7**
7." When we get shocked the current flows through our bodies and burn the cells to death. This could lead to death".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process	**3**	**21**	**14.3**
8. "To make electricity safe. We need to some safety measures".	**Coded** Science concept	**1**	**10**	**10.0**
9. "You must not overload the plugs or outlets. Don't connect too many appliances to one plug. The cables must have good insulation, do not connect and bind the cables, disconnect equipment that you are not using from the plugs, keep your hands dry when you are dealing with power, don't poke your fingers or anything in the plugs".	**Coded** Science concept	**1**	**59**	**1.7**
10. "The other important thing about electricity is that we need to conserve it. Why?"	**Coded** Science concept	**1**	**14**	**7.1**
11. "Producing electricity is expensive. If we use it without wasting, we reduced the cost of making it".	**Coded** Science concept	**1**	**17**	**5.9**
12." How do we conserve electricity? We switch off or unplug all the appliances that we are not using. Turn of the lights when you leave the room. Make use of solar charges for your cellphones. Do not take long warm showers. Those are some of the ways to save electricity".	**Coded** Science concept	**2**	**50**	**4.0**

13. "This brings us to the end of electricity. Tomorrow we shall do magnetism".	**Coded** Science concepts	**2**	**13**	**15.4**

Lexical density coding and calculations for utterances of lesson seven on magnetism by a novice teacher.

Utterance section	**Coding Notes**	**Number of content words**	**Total words**	**LD (%)**
1. "Now let's start with magnetism".	**Coded** Science concept	**1**	**5**	**2.0**
2. "The main word in magnetism is magnets. You cannot talk of magnetism without talking of magnets. Magnets attract certain materials".	**Coded** Science concept Words indicating categories of science objects. Words related to a definition of a science concept and shaping a scientific process.	**7**	20	35.0
3. "We have magnetic materials and non-magnetic materials".	**Coded** Science concept Words indicating categories of science objects.	**4**	7	57.4
4. "Magnetic materials are materials that are attracted by the magnets".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**5**	**10**	**50.0**
5. "Magnetic materials are also called ferrous materials because they attract magnetic materials".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**7**	**12**	**58.33**
6. "Non-magnetic materials are materials that are not attracted by magnets".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**5**	**10**	**50.0**
7. "Those materials that are attracted by magnets, there is something special about them. They contain iron".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**4**	**16**	**25.0**

8. "Examples of materials that are attracted by magnets are nickel, iron, steel, cobalt".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**7**	**12**	**58.3**
9. "The non-ferrous material are materials that are not attracted by the magnets".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	**3**	**12**	**33.3**
10. "Example are glass, plastics, papers, copper, and they do not contain iron".	**Coded** Words indicating categories of science objects	**2**	**12**	**16.7**
11. "We have two types of magnets. A horse shoe magnet (this one) and a bar magnet (this one)".	**Coded** Words indicating categories of science objects	**6**	**17**	**35.3**
12. "The bar magnet has two poles as you can see. The north pole and the south pole. The horse shoe is difficult to see the poles. Like poles repel and unlike poles attract".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects/concepts	**17**	**33**	**51.5**
13. "Magnets attract magnetic materials or ferrous materials".	**Coded** Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects	**6**	**7**	**85.7**
14. "And a free suspended magnet will point in the north south direction. For example, the one in the compass. The compass arrow points at the north direction or south direction".	**Coded** Words indicating categories of science objects	**1**	**30**	**3.5**
15."The magnets are having magnetic fields. What are the magnetic fields?"	**Coded** Science concept Words indicating categories of science objects	**5**	**11**	**45.5**
16. "They are around the magnet. This is the area around the magnet whereby the force of the magnets can be experienced or can be exerted".	**Coded** Science concept Words indicating	**4**	**24**	**16.7**
17. "We can draw magnetic field lines around magnetic fields".	**Coded** Science concept	**5**	**9**	**55.6**

18. "And the magnetic lines move from the north pole to the south pole of the magnet. We can confirm this with an experiment whereby we use a compass and the iron filings. Iron filings will show us the presents of magnetic field around the magnet. And the compass is having the arrows which shows the poles of the magnets. If you put it on the side or end of the pole it will point to north because magnetic field lines they move from north to south poles".	**Coded** Science concept Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects	**25**	**86**	**31.4**
19. "You have seen from the experiment the way the iron filings arrange themselves. They indicate the magnetic field line".	**Coded** Science concept Words indicating categories of science objects	**6**	**19**	**31.6**
20. "You have to know how to draw the magnetic field lines. With the arrows showing the directions. North and north field lines bent not touching one another. This is the same with south and south. South and north the field lines join one another".	**Coded** Science concept Words indicating categories of science objects	**13**	**44**	**30.0**
21. "Tomorrow we shall talk about electromagnetic induction".	**Coded** Science concept	**2**	**7**	**28.6**

Appendix D: Lexical density coding and calculations for utterances of lessons one to six on the topic of current by an experienced teacher.

Lexical density coding and calculations for utterances of lesson one on the topic of current by an experienced teacher

Utterance section	Coding notes	Number of content words	Total words	LD (%)
1. "Now we can calculate the current".	**Coded** Science concept Words frequently used in science indicating mathematical operation.	2	6	**33.3**
2. "Because we said the current is the flow of charges per unit of time so it can be calculated".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Variables frequently used in science (including the word unit) Words frequently used in science indicating mathematical operation.	7	19	**36.8**
3. "The current, the charges and the time and we calculate it using the formula as charge divided by time".	**Coded** Science concepts Words frequently used in science indicating mathematical operation. (including the word formula). Variables frequently used in science. Words frequently used in science indicating mathematical operation. (including the word formula).	8	19	**42.1**
4. "So, I represent the current, the charges is Q and the time is small t and this is current".	**Coded** Science concepts (in words and abbreviated) Variables (in words and abbreviated) frequently used in science.	**7**	19	**36.8**
5. "For example, we have three coulombs. The coulombs is what?"	**Coded** Units of science variables/concepts Number in words quantifying a science variables.	3	10	**30.0**
6. "The coulomb is the unit of charge. Which flows".	**Coded** Units of science variables/concepts Science concept Words related to a definition of a science concept and shaping a scientific process.	**3**	9	**33.3**

7. "If three coulombs of charges flow through a conductor in two seconds what current will it be?"	**Coded** Units of science variables/concepts Science concepts Words indicating categories/types of science objects. Words related to a definition of a science concept and shaping a scientific process. Number in words quantifying a science variables.	8	16	**50.0**
8. "The rule for calculation in Physical Science is first you have to write the formula right and then you identify the quantity from the scenario you are given and then you do the calculation. Here you must at least write it down. When you are calculating your writing must be going down".	**Coded** Words frequently used in science (indicating certain area of science). Words frequently used in science indicating mathematical operation. (including the word formula).	**6**	52	**11.5**
9. "So you use the formula current is charges divided by time".	**Coded** Science concepts. Words frequently used in science indicating mathematical operation. (including the word formula). Variables frequently used in science.	5	11	**45.5**
10. "The charges here is three and the current that flows though the conductor in two seconds is one point five amperes".	**Coded** Science concepts Numbers in words quantifying science variables (including the word point). Words related to a definition of a science concept and shaping a scientific process. Units of science variables/concepts Words indicating categories/types of science objects.	11	21	**52.4**
11. "You can also calculate the charges. The formula of the current you can also derive the formula to calculate the charges. So what is the formula to calculate the charges? Charge is?"	**Coded** Words frequently used in science indicating mathematical operation(including the word formula) Science concepts.	11	32	**34.4**

12. " Current times time, and time? charge divided by current".	**Coded** Science concepts Words indicating mathematical operation. Variables frequently used in science.	7	9	**77.8**
13. "Then the current is there in two types. There are two types of current- electron current and conventional current".	**Coded** Science concepts Numbers in words quantifying science concepts. Words indicating categories/types (thing/type relationship).	8	19	**42.1**
14. "The electron current is the movement of electrons in a circuit. and in electron current the electrons flow from negative to positive. That is what makes more difference. The flow of electrons from one terminal to another, which is from negative to positive. That is electron current".	**Coded** Science concepts Words indicating categories/types of science objects Words related to a definition of a science concept and shaping a scientific process Words shaping scientific process Antonymous words which are collocated with science concepts (and which indicate categories of science concepts).	17	47	**36.2**
15. "And conventional current is the agreement that current would flow from positive to negative terminal of a cell. So, this one is mainly on the direction of the electron flow".	**Coded** Science concepts Antonymous words which are collocated with science concepts (and which indicate categories of science concepts). Words related to a definition of a science concept and shaping a scientific process Words indicating categories/types (thing/type relationship).	11	29	**37.9**
16. "We go to electrical current in circuit".	**Coded** Science concepts. Words indicating categories/types science objects.	3	6	**50.0**
17. "So, for current to flow there must be a complete circuit. There must be complete circuit and this circuit when we say its complete it is when there is no a gap. The circuit must contain a source, the	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process Words indicating categories/types of science objects (including words	13	42	**31.0**

charges and the switch and bulb".	describing the state of an object, such as complete).			
18. "This circuit is not complete because the switch is open. So, there will be no current flow. The current will not reach this component the bulb".	Science concepts Words related to a definition of a science concept and shaping a scientific process Words indicating categories/types of science objects (including words describing the state of an object, such as complete and open).	9	26	**34.6**
19. "This circuit we call it a complete circuit because it has a closed circuit. This is a cell. If it is more than one cell it is called a battery. This is a switch. Which is a close switch. And this is a bulb. This is a conductor".	**Coded** Science concepts Words indicating categories/types of science objects (including words describing the state of an object, such as closed and open). Number in words quantifying science objects/concepts.	13	40	**32.5**
20. "And the only difference between this two circuits is the open or closed switch. Here there is no current flow and here the current flows and the bulb will be hot".	**Coded** Science concepts Words shaping scientific process Words indicating categories/types of objects (including words describing the state of an object, such as hot, closed and open) Number in words quantifying science objects.	11	31	**35.5**
21. "Now, we have two types of circuits- a parallel circuit and a series circuit.	**Coded** Numbers in words quantifying objects Words indicating categories of science objects Words related to to definition of a science concept and shaping scientific process, having antonymous sense relation. Numbers in words quantifying science objects	6	12	**50.0**
22. "A parallel circuit is when the components are connected in branches, the series circuit when the components are connected one after another in one row.	**Coded** Science concepts Numbers in words quantifying objects Words indicating categories of objects (including words describing	12	30	**40.0**

This one is? Parallel or series?"	the state of an object, such as branches and row). Words related definition of a science concept and shaping scientific process, having antonymous sense relation.			
23. "This two circuits they are differ in terms of current flow, they are differing in terms of resistance and they are also differ in terms of voltage".	**Coded** Numbers in words quantifying objects Science concepts. Words indicating categories of science objects Words shaping scientific process. Numbers written in words adding scientific meaning (indicating categories/types)	6	27	**22.2**
24. "So we are going to talk about this circuits concerning the current, concerning the voltage and also the resistance".	**Coded** Science concepts Words indicating categories/types of science objects.	4	19	**21.1**
25. "So current first. What is the difference between current in series and current in parallel? Current in series and current in parallel. Current in series is the same at all points while current in parallel is not the same it is different".	**Coded** Science concept Words like point, same and different (frequently used in science, shaping a science concept/process). Words indicating categories/types(antonymy) sense relation	16	42	**38.1**
26. How difference it is? If the branches are having the same resistance for example here the resistance is the same then the current will divide equally".	**Coded** Science concepts Words indicating categories of objects Words like same (frequently used in science). Words like divide and equally(translate into a mathematical operation)	8	26	**30.8**
27. "Let me say the current here is eight and one branch will be four and in the next one also will be four.	Science concepts Numbers in words quantifying science concepts/objects. Words indicating categories of science objects .	7	23	**30.4**

28. " But if the resistance is different than it will be distributed according to the resistance of each bulb. The bulb with more resistance it will have high or less current. the bulb with more resistance it will have low current or high current? Low current. And the one with low resistance it will have? high current".	**Coded** Words like different, high, less and low (frequently used in science). Words indicating categories of science objects Science concepts	21	56	**37.5**
29. "They say the current entering the branch is the same as the current leaving the branch".	**Coded** Words indicating categories of science objects. Science concept Words related to definition of a science concept and shaping scientific process.	7	16	**43.8**
30. " Here there is four here there is four. The total current is eight. The total current you add together the current in the branches together to get the eight. For example, if here there is three amperes and here there is five amperes to get the total you add them".	**Coded** Science concepts Words like total and add (frequently used in science to indicate a mathematical operation). Words indicating categories of science objects Numbers in words quantifying science concepts.	17	50	**34.0**
31. "And which bulb is may be having high resistance between the two? The one with three amperes".	**Coded** Science concepts Words shaping a scientific process. Words indicating categories of science objects Numbers in words quantifying science concepts. **Uncoded** Numbers in words referring to an option.	5	17	**29.4**
32. " Let's say you are given the total current. It is eight and you are given here there is eight amperes and you are asked to find the current in this bulb. How will you do it? You subtract the current of the one which you are given from the total current then	**Coded** Science concepts Words like total and subtract (frequently used in science to indicate a mathematical operation). Words indicating categories of science objects Numbers in words quantifying science concepts.	13	62	**21.0**

you get the current of the bulb you were asked".	**Uncoded** Numbers in words referring to an option.			
33. "The current entering the branch in parallel is equal to the sum of current leaving the branch".	**Coded** Science concept Words having antonymous relationship, shaping scientific process or definition of a science concept. Words indicating categories of science objects Words like sum and equal (frequently used in science to indicate a mathematical operation).	9	17	**52.9**
34. "If the bulb or resistance are identical the current divide equally. If the resistance is not identical the current will also not be equal. The bulb with more resistance will have low current and the other one with low resistance will have more current".	**Coded** Science concepts Words related definition of a science concept and shaping scientific process, Words that are frequently used in science. Words indicating categories of science objects. Words like equal and divide (frequently used in science to indicate a mathematical operation).	17	44	**38.6**
			Mean	**37.5**

Lexical density coding and calculations for utterances of lesson two on the topic of voltage by an experienced teacher.

Utterance section	Coding notes	Number of content words	Total words	LD (%)
1. "What is voltage or potential difference?"	**Coded** Science concepts	3	6	**50.0**
2. Voltage is the ability to drive the charge around the circuit. The ability to drive a charge around the circuit. We said current is the flow of charge. The voltage is the ability of the conductor".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	10	35	**28.6**
3. "The ability of the source, the battery or the cell to	**Coded** Science concepts	5	17	**29.4**

drive the charges around the circuit".	Words indicating categories of science objects.			
4. "So, this potential difference is the one which is called the voltage".	**Coded** Science concepts	3	12	**25.0**
5. "The cell is having two terminals - the positive and the negative".	**Coded** Numbers in words quantifying science objects Words indicating categories of science objects.	5	11	**45.5**
6. "Now these terminals are having different potentials".	**Coded** Words indicating categories of science objects. Words related to a definition of a science concept and shaping a scientific process.	2	7	**28.6**
7. "So, because the electricity or the charges flow from negative to positive then one terminal will have more force to push the charges to another terminal which is having a low force or the low ability".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	13	35	**37.1**
8. "That difference is the one that make the charges to flow along the conductor".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects. **Uncoded** Numbers in words indicating an option.	3	14	**21.4**
9. "Now there is a difference between voltage in series and voltage in parallel.	**Coded** Science concepts Words indicating categories of science objects.	4	12	**25.0**
10. "In series the voltage is different".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	3	6	**50.0**
11. "You know in series the current is the same but in series the voltage is different".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	6	16	**37.5**

12. "While in parallel the voltage is the same at all points".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	4	11	**36.4**
13. "So in series the voltage across individual component is equal to voltage in the whole circuit".	**Coded** Science concepts Words frequently used in science for mathematical operations. Words indicating laws in physics/science Words indicating categories of science objects.	6	16	**37.5**
14. "Here you can read the voltage in series circuit".	**Coded** Science concepts Words indicating categories of science objects/concepts.	3	9	**33.3**
15. "While in parallel the voltage across the branch is equal to the voltage across the battery".	**Coded** Science concepts Words indicating categories of science objects/concepts. Words frequently used in science indicating mathematical operation.	6	16	**37.5**
16. "Here you can read the voltage in parallel circuits".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words indicating categories of science objects/concepts.	3	9	**33.3**
17. "Voltage can be calculated by using a formula".	**Coded** Science concepts Words frequently used in science indicating mathematical operation. (including the word formula).	3	7	**42.7**
18. "The formula is V equals I times R".	**Coded** Words frequently used in science indicating mathematical operation. (including the word formula). Formula in words	6	8	**75.0**
19. **"**Say here the resistance is five Ohms and the current is two Amperes the voltage will be ten Volts"**.**	**Coded** Science concepts Numbers in words quantifying science concepts/objects. Units of science concepts/ variables	9	19	**47.4**
			Average	**38.0**

Lexical density coding and calculations for utterances of lesson three on the topic of electrical resistance by an experienced teacher.

Utterance section	Coding Notes	Number of Content Words	Total words	LD %

1."What is resistance?"	**Coded** Science concepts	1	3	**33.3**
2. "The opposition to the current flow or the force which oppose the movement of the charges along the conductor".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	5	19	**26.3**
3. "Resistance is measured in ohms and it is measured using the ohm meter".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Units of science concepts/ variables Words indicating categories of science objects.	6	12	**50.0**
4. "It can also be determined from the quantity of current and voltage by using the formula voltage divided by current".	**Coded** Science concepts Words frequently used in science quantifying science concepts. Formula in words (Words frequently used in science indicating mathematical operation)	7	20	**35.0**
5. "And then the resistance in parallel and resistance in series".	**Coded** Science concepts Words indicating categories of science concepts.	4	10	**40.0**
6. " In series the total resistance of the resistor is equal to the sum of resistance of individual resistors".	**Coded** Science concepts Words indicating categories of science objects./concepts. Words frequently used in science indicating mathematical operation.	8	18	**44.4**
7. "Let's say this is a series circuit and the total resistance here is equal to the resistance here".	**Coded** Science concepts Words indicating categories of science objects. Words frequently used in science indicating mathematical operation.	6	17	**35.3**
8. "That is why we have a formula that says RT equals to R1 plus R2. You just add the resistance in the circuit".	**Coded** Science concepts Words indicating categories of science objects. Words frequently used in science indicating mathematical operation (including the word formula) Symbols of science concepts	9	22	**40.9**
9. "But resistance in parallel we have the formula which is one over RT which is the total, which is 1 over R1 plus	**Coded** Science concepts Words indicating categories of science objects.	10	30	**33.3**

1 over R2 it depends how may resistors are there".	Words frequently used in science indicating mathematical operation (including the word formula), Formula in words Symbols of science concepts			
10. "If there are four you go on like that. Then what you do you look for the common denominator of the number for example you say R1 there is 3 ohms and resistor two there is 2 ohms and then you look for common denominator of three and two which is six. Three goes in six how many times? Two plus three is? and then you do reciprocal and the answer will be 1.2 ohms".	**Coded** Unit of science concepts Numbers in words quantifying science objects/concepts. Words indicating categories of science objects. Words frequently used in science indicating mathematical operation. Formula in words. Numbers in words used in mathematical operation. Symbols of science concepts	17	73	**23.3**
11. "Now can we end with the factors that are affecting resistance".	**Coded** Science concept Words indicating categories of science concepts.	2	9	**22.2**
12. "The factors that affect resistance are temperature of the conductor, the diameter of the conductor, the type of the conductor, the diameter and cross sectional area of the conductor and the length of the conductor".	**Coded** Science concept Words indicating categories of science concepts. Words indicating categories of science objects. Words frequently used in science to indicate categories.	14	35	**40.0**
13. "How does those three things you have mentioned affects the resistance? Let's consider the temperature".	**Coded** Science concepst	2	15	**13.3**
14." As temperature increases the resistance also increases and low the temperature the lower the resistance and the relationship between this two is called they are directly proportional".	**Coded** Science concepts Words frequently used in science for mathematical ratio/operation. **Uncoded** Numbers in words referring to an option	6	27	**22.2**
15."The type of a conductor how does it affect the resistance?"	**Coded** Science concept Words indicating categories of science objects.	2	10	**20.0**
16. "Materials that are good conductors they have low resistance and. They have low temperature".	**Coded** Science concepts Words indicating categories of science objects	4	14	**28.6**

17. "Can you give me example of one material which is a good conductor of electricity? And one with low resistance".	**Coded** Science concepts Words indicating categories of science objects.	4	19	**21.1**
18. "Nichrome wire".	**Coded** Words indicating categories of science objects.	2	2	**100**
19. " We also have one factor which is the length of the conductor".	**Coded** Words indicating categories of science concepts. Words indicating categories of science objects.	3	12	**40.0**
20. "The longer the conductor the higher the resistance and they are also directly proportional".	**Coded** Science concept Words indicating categories of science objects. Words frequently used in science for mathematical ratio/operation	4	14	**28.6**
21. "And we also have the diameter or the cross sectional area of the conductor. How does it affect the resistance?"	**Coded** Science concept Words indicating categories of science objects. Words frequently used in science to indicate categories.	6	20	**30.0**
22. "So these ones are indirectly proportional. This one is having low resistance (thick) and this one is having high resistance (thin)".	**Coded** Science concepts Words frequently used in science for mathematical ratio/operation. **Uncoded** Numbers in words indicating options	4	22	**21.1**
			Average	**34.0**

Lexical density coding and calculations for utterances of lesson four on the topic of electrical resistance by an experienced teacher.

Utterance	Coding notes	Number of Content Words	Total Words	LD (%)
1. "Yesterday we have been talking about factors that affecting resistance".	**Coded** Science concepts Words indicating categories of science concepts.	2	10	**20.0**
2. " There are four of those factors. Namely- temperature of, the length of the conductor, the diameter of the conductor and type of the conductor. And you must be able to explain how these	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words related to a definition of a science concept and shaping a scientific process.	10	37	**27.0**

conductors affect the resistance".				
3. "The calculation for resistance in parallel and series we did it yesterday".	**Coded** Science concepts Words indicating categories of science concepts/objects Words frequently used in science indicating mathematical operation.	4	12	**33.3**
4. "But today we are going to talk about the relationship between current and voltage in electrical conductor".	**Coded** Science concepts Words indicating categories of science objects.	4	18	**22.2**
5. "And yesterday we learned what is current. What is current?"	**Coded** Science concepts	2	10	**20.0**
6. "Current is a flow of charge. And voltage is the potential difference that exist between two point is a circuit".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words related to a definition of a science concept and shaping a scientific process.	9	18	**50.0**
7. "Therefore, you won't have current if we don't have potential difference".	**Coded** Science concepts	3	11	**27.3**
8. " Potential difference is the force which allows flow of charges along the conductor forcing the charges to move and that is what we call current".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	9	25	**36.0**
9. "And now, this means that if there is a force. We say potential difference is the force that drives the current".	**Coded** Science concepts	5	20	**25.0**
10. "let say if the potential difference is high how does it affect the current?"	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words related to a definition of a science concept and shaping a scientific process.	4	14	**28.6**
11. "The current will also be high. If the voltage is low the current will also be low. So, that is the relationship we are going to focus on today".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	5	29	**17.2**

12. "And in some conductors, good conductors of electricity if current increases voltage will also increase or if voltage increases current will also increase".	**Coded** Science concepts Words indicating categories of science objects.	7	23	**30.4**
13. "So, that is what we call directly proportional to each other".	**Coded** Words frequently used in science for mathematical ratio/operations.	2	11	**18.2**
14. "If the current and voltage are directly proportional to each other, then we say they obey the ohm's law".	**Coded** Science concepts Words frequently used in science for mathematical ratio/operations. Words indicating laws in physics/science.	6	19	**35.6**
15. "What does the ohm's law say?"	**Coded** Words indicating laws in physics/science.	2	6	**33.3**
16. "In a metallic conductor at a constant temperature the current is directly proportional to the potential difference".	**Coded** Science concepts Words frequently used in science for mathematical ratio/operations. Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	9	15	**60.0**
17. "The current through a metallic conductor at a constant temperature is directly proportional to the potential difference because in ohmic conductors the resistance is always constant".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects. Words frequently used in science for mathematical ratio/operations.	13	24	**54.2**
18. "What change the voltage or flow of current?"	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	3	8	**37.5**
19. "The flow of current is changed by resistance. If the resistance is high or changing the current also changes".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	6	19	**31.6**
20. "And that is the reason why we talked about the factors that affect electricity or the flow of current".	**Coded** Science concepts Numbers in words quantifying science concepts/objects	4	19	**21.1**

	Words related to a definition of a science concept and shaping a scientific process. of definition of electricity/current/charges)			
21. "We say the high the temperature the more the resistance, and the resistance is the one which is reducing current".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	5	20	**25.0**
22. "So, if the temperature was low at first, then the current will be high. Now, if the temperature increases the current will also? Will also reduce".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	7	27	**25.9**
23. "You used to see when you are charging the phone, after sometime the charger is hot. So, that is the temperature of the conductor we are talking about".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	5	28	**17.9**
24. "And the conductors now, not all electrical conductors obey the ohm's law".	**Coded** Science concepts Words indicating laws in physics/science. Words indicating categories of science objects.	5	12	**41.7**
25. "Because some conductors when charges pass through them they get hot, these conductors that change the temperature are non-ohmic conductors".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects/concepts.	7	20	**35.0**
26. "Non- ohmic conductors are for example the filaments of the bulb. As it gets hot the current is also low".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects.	7	20	**35.0**
27. "There are also materials that obey ohm's law and we call them the ohmic conductors".	**Coded** Words indicating laws in physics/science. Words indicating categories of science objects.	5	15	**33.3**

28. "Ohmic conductors are good conductors of electricity for example?"	**Coded** Science concepts Words indicating categories of science objects.	4	8	**50.0**
29. "Copper, nichrome wire".	**Coded** Words indicating categories of science objects.	3	3	**100.0**
30. "We can tell from the graph that a conductor is ohmic or non ohmic conductor".	**Coded** Words indicating categories of science objects. Words frequently used in science indicating mathematical operation. (including the word graph).	6	14	**42.9**
31. "Let's say here there is voltage on the y-axis and current (I) on the x-axis. The graph for ohmic conductor will go straight, because the voltage and the current are directly proportional".	**Coded** Science concepts (in words and symbols) Words indicating categories of science objects. Words frequently used in science indicating mathematical operation. (including the word graph and axis). Words frequently used in science for mathematical ratio/operations.	11	30	**36.7**
32. "Here we can see that the current increases as the voltage also increases".	**Coded** Science concepts	2	13	**15.4**
33. "This only happens in ohmic conductors for example copper, copper wire, nichrome wire".	**Coded** Words indicating categories of science objects.	7	12	**58.3**
34. "Now how does a graph of non-ohmic conductor looks like?"	**Coded** Words indicating categories of science objects. Words frequently used in science indicating mathematical operation. (including the word graph).	3	8	**37.5**
35." It is not straight like this one".	**Coded** None **Uncoded** Numbers in words indicating an option	0	6	**0**
36. "Now we have the graph which represents the a non ohmic conductor. Here we have voltage in volt".	**Coded** Science concepts Units of science concepts/ variables Words frequently used in science indicating mathematical operation. (including the word graph).Words related to a definition of a science concept and shaping a scientific process.	5	15	**33.3**

	Words indicating categories of science objects.			
37. "Always write the name of the quantity and the unit".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words related to a definition of a science concept and shaping a scientific process. Units of science concepts/ variables Words indicating categories of science objects. Words frequently used in science indicating unit and quantity.	2	10	**20.0**
38." Now the non ohmic conductors do not obey the ohm's law. The voltage will not be directly proportional to the current. As long as it is not straight as long as it bent down or up. It is a non ohmic conductor".	**Coded** Science concepts Words frequently used in science for mathematical ratio/operations. Words indicating laws in physics/science Words indicating categories of science objects.	10	29	**34.5**
39. "Why does it give a drawing or curve like this? It is indirectly proportional".	**Coded** Words frequently used in science for mathematical ratio/operations.	2	14	**14.3**
40. "Even if the voltage increases. You can see from the graph the voltage was increasing from the beginning. And here maybe the temperature increases and it affects the current. Even if the voltage is high the current will not increase because there is high resistance which is opposing the flow of charges".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words frequently used in science indicating mathematical operation. (including the word graph).	12	52	**23.1**
41. "Here at first it was obeying the ohms law up to here to here and from three up to four here you can see that the voltage is increasing, from three to four the current is just zero point five".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words indicating laws in physics/science	11	40	**27.5**
42. "This means there is a force that opposing the movement of charges. There is a high resistance. Therefore, the current will not be high. The current can be constant or also low".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	9	30	**30.0**

43. "Non- ohmic conductors we have bulbs. They do not obey ohm's law".	**Coded** Words indicating laws in physics/science Words indicating categories of science objects.	5	11	**45.5**
44. "You can also do this by calculating. You can have a table of current and voltage and then you calculate resistance".	**Coded** Science concepts Words frequently used in science indicating mathematical operation.	5	20	**25.0**
45. "The formula to calculate the resistance is Voltage divided by current".	**Coded** Science concepts Words frequently used in science indicating mathematical operation. (including the word formula). Formula in words	6	10	**60.0**
46. "What you need to know is that if you calculate the resistance at any point here you should get the same answer, for ohmic conductor".	**Coded** Science concepts Words indicating categories of science objects. Words frequently used in science indicating mathematical operation.	4	25	**16.0**
47. "But here you will not get the same answer. And that means that that conductor is an non ohmic conductor".	**Coded** Words indicating categories of science objects.	3	16	**18.6**

Lexical density coding and calculations for utterances of lesson five on the topic of power by an experienced teacher.

Utterance	Coding notes	Number of content words	Total words	LD %
1. "Today we are going to look at the topic of power".	**Coded** Science concepts	1	11	**9.0**
2. "Power is related to energy".	**Coded** Science concepts	2	5	**40.0**
3. "Power in general is the rate of transfer of energy".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	5	10	**50.0**
4. " Now this one is electrical power. What is electrical power?	**Coded** Science concepts	4	10	**40.0**

5. “Power itself is the rate of doing work and electrical power is the rate of transfer of electrical energy”.	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	13	18	**72.2**
6. “Because work is the transfer of energy from one form to another”.	**Coded** Science concepts **Uncoded** Number in words referring to an option.	2	13	**15.4**
7. “Therefore, when electrical energy is transferred to other forms for example the energy that goes to the bulb is transferred to light energy”.	**Coded** Science concepts Words indicating categories of science objects.	6	23	**26.1**
8. “When electrical energy is moving along the conductor or electrical energy is used in different equipment we need that energy in different forms that we need”.	**Coded** Science concepts Words indicating categories of science objects.	6	26	**23.1**
9. “From the bulb we need light therefore electrical energy is transferred to light in the bulb”.	**Coded** Science concepts Words indicating categories of science objects.	6	16	**37.5**
10. “How about the oven. Cooking oven?”	**Coded** None	0	6	**0**
11. “Electrical energy is transferred to heat energy”.	**Coded** Science concepts	4	7	**57.1**
12. “How about the microphone?”	**Coded** None	0	4	**0**
13. “Electrical energy is transferred to movement and to sound”.	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process.	4	10	**40.0**
14. **“**When we are talking about power here it is how fast the object for example the bulb, the oven or whatever is using electricity. How fast it changing the electrical energy into the desired kind of energy. It can be heat, light, sound, movement etcetera”.	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words indicating categories of science objects. .	10	45	**22.2**
15. “Therefore, electrical power can be calculated, can be measured and can be calculated. The unit of electrical power is?”	**Coded** Science concepts Words frequently used in science indicating mathematical operation. (including the words measure and unit).).	8	19	**42.1**

16. "Watts is the unit of electrical power".	**Coded** Science concepts Words frequently used in science indicating unit and quantity.Units of science variables/concepts	4	6	**66.7**
17. "And to calculate the electrical power we use the formula which is the voltage multiplied by current".	**Coded** Science concepts Words related to a definition of a science concept and shaping a scientific process. Words frequently used in science indicating mathematical operation. (including the word formula). Formula in words	7	17	**41.2**
18. "Example an electrical kettle allows a current of five amperes when connected to a two hundred and thirty Volt mains. Now find its power".	**Coded** Science concepts Numbers in words quantifying science concepts/objects Words indicating categories of science objects. Units of science concepts/ variables	10	21	**47.6**
19. "The first thing you do is to write down the formula. The formula is always having a mark which is power equals to voltage times current. The answer will be one thousand one hundred and fifty Watts".	**Coded** Numbers in words quantifying science concepts/objects Units of science concepts/ variables Formula in words. Words frequently used in science indicating mathematical operation. (including the word formula).	13	36	**36.1**

Appendix E : Letter of permission to the Regional Director of Education

RECEIVED 27 APR 20

Efraim Muzambani

P.O. Box 3388

Ongwediva

23 April 2018

The Regional Director of Education

Mrs. Hileni Amukana

Oshana Region

Namibia

Dear Madam,

REQUEST FOR PERMISSION TO CONDUCT MEd RESEARCH AT SCHOOL [redacted] AND [redacted]

My name is Efraim Muzambani, and I am a Masters of Education student at Rhodes University (RU) in Grahamstown, South Africa. The research I wish to conduct for my full MEd thesis requires me to audio record teacher talk during grade 10 Physical Science lessons. This research will be conducted under the supervision of Mr. Kavish Jawahar.

This letter serves to seek formal consent to approach the teachers, [redacted] and [redacted] at [redacted] and [redacted] School, respectively. For this reason, I request your permission to visit the two schools on during the week starting 21 May to conduct my research as outlined in my research proposal.

I attach copies of the consent and assent forms to be used in the research process. I also attach an ethical clearance letter from Rhodes University. As part of this I undertake to ensure that the name of the schools and all participants will be replaced with pseudonyms (except for Principal and yourself) and that all the audio recordings will be accessible only to me and my supervisor.

Upon completion of the study, I undertake to provide you and the teachers with access to the research findings. If you require any further information, please do not hesitate to contact me on 0812818315 and casto800@gmail.com.

Thank you for your time and consideration in this matter.

Yours sincerely

Efraim Hiamueze Muzambani (17M8219). Rhodes University

Appendix F: Letter of permission to the Principal of the school

Efraim Muzambani

P.O. Box 3388

Ongwediva

23 April 2018

The School Principal

[redacted]

Oshakati

Dear Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT [redacted]

My name is Efraim Muzambani, and I am a Masters of Education student at Rhodes University (RU) in Grahamstown, South Africa. The research I wish to conduct for my full Masters's thesis requires me to audio record teacher talk during eight grade 10 Physical Science lessons. This research will be conducted under the supervision of Mr. Kavish Jawahar.

This letter serves to seek formal consent to approach teache[redacted]for this reason, I request your permission to visit your school during the weeks starting 21 May 2018 to conduct my research as outlined in my research proposal.

I attach copies of the consent and assent forms to be used in the research process. Hereto attached please find the ethical clearance letter from Rhodes University. As part of this I undertake to ensure that the name of the schools and all participants will be replaced with pseudonyms except for the Regional Director and yourself and that all the material I collect as part of the research will be accessible only to myself and my supervisor.

Upon completion of the study, I undertake to provide you and the teachers with access to the research findings. If you require any further information, please do not hesitate to contact me on 0812818315 and casto800@gmail.com.

Thank you for your time and consideration in this matter.

Yours sincerely

Efraim Hiamueze Muzambani (17M8219). Rhodes University

[redacted]

Appendix G: Letter of invitation to the participants

Efraim Muzambani

P.O. Box 3388

Ongwediva

9 April 2018

TO: [redacted]

[redacted]

Oshakati

Dear Madam

Re: Invitation to participate in a research study

You are invited to participate in a research study entitled "Exploring the lexical and Semantic access afforded by two Physical Science teachers' talk during Grade 10 Electricity and Magnetism lessons in Namibia". The aim of this research is to explore the Physical Science teacher talk during grade 10 electricity and magnetism lessons, in terms of knowledge-building and expression in science discourse.

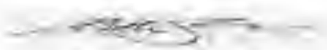
The research will be undertaken through audio recorded lessons. Your participation in the research is anonymous and your identity will not be revealed except to the school principal and regional director as their informed consent is also required. The collection of this data will require approximately two weeks and will not disturb your teaching.

If you agree to participate, I will explain in more detail what would be expected of you, and provide you with the information you need to understand the research, on 27 April 2018.These guidelines would include potential risks, benefits, and your rights as a participant. The study has been approved by the Ethics Committee of the Faculty of Education and hereto attached find the letter of ethical approval.

Participation in this research is voluntary and a positive response to this letter of invitation does not oblige you to take part in this research. To participate, you will be asked to sign a consent form to confirm that you understand and agree to the conditions, prior to audio recordings of your lessons. Please note that you have the right to withdraw at any given time during the study.

Thank you for your time and I hope that you will respond favourably to our request.

Yours sincerely,



Efraim Hlamueze Muzambani (17M8219). Rhodes University

Appendix H : Proposal and ethical clearance approval

RHODES UNIVERSITY

Grahamstown • 6140 • South Africa

EDUCATION FACULTY • PO Box 94, Grahamstown, 6140
[illegible]

PROPOSAL AND ETHICAL CLEARANCE APPROVAL

Ethical clearance number 2018.02.14.04

The minute of the EHDC meeting of 01 February 2018 reflect the following:

2018.02.14 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:

Mr [illegible] (17M8219)

Topic: Exploring the lexical and semantic [illegible] afforded by novice and experienced Namibian Physical Science teachers' talk during Electricity and Magnetism lessons

Supervisor: Mr [illegible]

Decision: Approved

This letter confirms the approval of the above proposal at a meeting of the Faculty of Education Higher Degrees' Committee on the 01 February 2018.

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

Ms [illegible]
Secretariat of the EHDC, Rhodes University
14th February 2018