Exploring Grade 10 physical science teachers' pedagogical approaches to the Electricity topic in selected Vryheid rural schools, KwaZulu-Natal Province

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Abstract

In a context often characterised by lack of resources, with its peoples' agencies often ignored, how do teachers teach difficult yet practical science topics in rural classrooms? This question was asked in a context where teaching is described as a complex task. Without overlooking teachers‘ individual agency, teaching science in rural schools is an arduous undertaking. Science teachers require sufficient and appropriate content knowledge and pedagogical knowledge for enhanced science teaching and learning experiences. Understanding teachers‘ pedagogical knowledge was the interest of this study. Therefore, the purpose of this study was to explore teachers‘ pedagogical approaches during the Electricity lessons in Grade 10 rural classrooms and examine teachers‘ pedagogical reasoning for the observed teaching approaches. The paucity of physical science education research in rural schools has not been able to offer an account of teachers‘ pedagogical approaches and what influences their pedagogical practices within rural classrooms. Hence, the current study as introductory for other science education researchers in researching physical science teaching and learning in rural schools. The present study used Mavhunga‘s (2012) topic specific pedagogical content knowledge (tsPCK) as a theoretical framework focusing on all five components of the theory. To supplement tsPCK, Scott et al.‘s. (2011) pedagogical link-making (PLM) was also used in identifying and discussing the nuances of teachers‘ pedagogical approaches during Electricity lessons.

I used a collective case study design and adopted a qualitative research approach and classroom observations, video-stimulated recall interviews (VSRI‘s), and semi-structured interviews as methods of data generation. The case study focused on three teachers from Vryheid rural schools in KwaZulu-Natal Province of South Africa, to investigate their classroom practices, particularly, pedagogical approaches to Electricity topic and factors that shape their teaching of the topic. The three teachers were purposefully and conveniently selected. To guide this case study investigation, the main research question of the study was: *How do Grade 10 rural physical science teachers teach the Electricity topic?*

The findings of this study revealed that the teaching of Electricity topic requires multiple representations at symbolic, macro, and sub-microscopic levels; and that explicit links of these representations are vital for science knowledge building. Teachers used mostly symbolic level, with some teachers limitedly representing the Electricity topic macroscopically through practical work (hands-on practical work and demonstrations). Important also was the contextualized level of representations including analogies that teachers used to teach the topic. Moreover, teachers constantly worked with learners‘ prior knowledge in their facilitation methods while also considering curricular sequencing and content skills linkage made within and across the lessons. Also, some observed electricity concepts or processes proved to be difficult for teachers to teach, while, I acknowledge the various conceptual teaching approaches that teachers used to ensure deep understanding of the topic of Electricity including those concepts that seemed difficult to teach. Other observable teachers‘ approaches included the dominance of question and answer teaching approach and teacher-centered approach, with some subject-matter centered approach and limited learner-centered approach. All three teachers taught the same topic differently.

During VSRI and semi-structured interviews, teachers commented on their teaching for assessment purposes. Teachers‘ pedagogical approaches were influenced by various factors including teachers‘ teaching and learning experiences, learners‘ prior knowledge, teaching for compliance, teaching for assessment (examination), availability and appropriate use of science laboratory apparatus for Electricity topic. Given the findings of this study, I recommend among other things, research intervention intending to equip rural teachers with pedagogical skills for teaching physical science topics including Electricity topic.

Keywords: *Electricity topic, pedagogical approaches, rural, teaching, physical science.*

Declaration

I **<u>SPHAMANDLA ZULU</u> (700650)** declare that this research study is my own work. It has not been submitted before for any other degree or examination in any other university. All the work taken directly from other works has been cited accordingly and the full list of references has provided. I fully understand that the University of the Witwatersrand will take disciplinary action against me if evidence suggests that this is not my own unaided work or that I failed to acknowledge the sources of the ideas or words in my writing.

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Dedication

I dedicate this dissertation to my pillar, my mother, Sizakele Mathenjwa. Thank you for always being there for me. To the highest God, thank you Lord, this dissertation would not have been possible without your guidance and strength. May the glory be unto you Lord!

List of Abbreviations

ACE	Advanced Certificate in Education
BEd	Bachelor of Education
CAPS	Curriculum and Assessment Policy Statement
CK	Content Knowledge
Covid-19	Coronavirus disease
CPD	Continuous professional development
CSA	Curricular Saliency
CTS	Conceptual Teaching Strategies
DBE	Department of Basic Education (Republic of South Africa)
EFAL	English First Additional Language
emf	Electromotive force
ePCK	Enacted Pedagogical Content Knowledge
FAL	First Additional Language
FET	Further Education and Training
IEA	Interactive / Evaluative / Authoritative communicative approach
ILSQ	Index of Learning Style Questionnaire
Inter/Sen	Intermediate and Senior phase
IRC	Initiation – response – confirmation
ITE	Initial Teacher Education
KZN	KwaZulu-Natal
LCA	Learner-Centered Approach
LMPC	Link-making to promote continuity
LMSS	Link-making to develop a scientific story
LOLT	Language of Learning and Teaching
LPK	Learner Prior Knowledge

MEd	Master‘s in Education
NPDE	National Professional Diploma in Education
NOS	Nature of Science
NS	Natural Science
NSC	National Senior Certificate
NSNP	National School Nutrition Programme
PCK	Pedagogical Content Knowledge
PG	Postgraduate
PGCE	Postgraduate Certificate in Education
PLM	Pedagogical Link-Making
PSAT	Physical Science Achievement Test
QATA	Question and Answer Teaching Approach
QCA	Qualitative Content Analysis
RCM	Refined Consensus Model (of PCK)
REP	Representations
SADC	South African Development Community
SGB	School Governing Body
SMC	Subject-Matter Centered
SMK	Subject Matter Knowledge
SMT	School Management Team
SP	Scientific Practices
TCA	Teacher-Centered Approach
TE	Teaching Experience
TIMSS	Trends in Mathematics and Scientific Study
TLSM	Teaching and learning support material
tsPCK	Topic-specific Pedagogical Content Knowledge
UNESCO	United Nations Educational, Scientific and Cultural Organization

VSRI	Video-Stimulated Recall Interviews
WDT/L	What is difficult to teach or learn
Wits	University of the Witwatersrand

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CHAPTER 1

Perspectives on the Teaching and Learning of the Electricity topic

1.1. The Researcher's positionality

Before I engage with the academic debates on the status and teaching of Electricity topic, I present my motivation for conducting this study. As a researcher, my past experiences with rurality, the teaching and learning of and, later, lecturing on the Electricity topic, and integrating everyday knowledge and formal science knowledge have influenced the conceptualisation of this study. In addition, the experience has shaped how I carried-out and eventually made sense of science knowledge in this research study. This is in accordance with Vygotsky‘s (1978) and Bernstein‘s (1996) conception of past experiences which influences how we construct knowledge. It is therefore important to talk about my previous experiences, and my personal identities that have influenced the conceptualisation, the research processes, and the reporting of the findings in this study. Accordingly, what I observed and analysed is not determined simply by the characteristics of the thing observed (Poni, 2014) but also from the perspective of the observer. Nonetheless, it is important to note that I remained loyal to the objective principles of this research study and the findings are discussed within their context, guided by both the aims of the study and the identified theoretical and analytical frameworks.

1.1.1 Where I come from: Life and schooling experiences

I was born and raised in a village called Ngongomane (near Nongoma town in Zululand District, KwaZulu-Natal (KZN) Province in South Africa), and I lived with my mother and four siblings until I was ready to start school in the year 2000. My family subscribed to the values of Christianity but also practiced the traditional African religion, as my maternal grandfather was a *sangoma* (traditional healer). The whole Ngongomane Village was purely Black dominated and spoke the IsiZulu language, and even our primary school was an IsiZulu-speaking school, where we literally learnt everything in IsiZulu until Grade 5. By Grade 6, there was a mixture of English, but IsiZulu language still dominated classroom talk. My primary school, William Booth Primary School was/is a no-fee public church primary school located at Mountain View, KwaZulu-Natal Province, South Africa. Then (early 2000), we used to pay a school fee of R50 per year. The school was approximately 15 kilometres from home. Between home and school there was no road but we used an *indlela* (walking trail, see example in Photograph 1) on a mountainous area and we had to pass through four rivers to get to school. During summer seasons it was difficult to pass through the Intombothi River because it was huge and heavy rain made it impossible to cross and I would have to return home. So rural life was interesting because in summer we would leave our textbooks at school fearing that it would rain while we were on our way home, and in winter it was difficult to hold a plastic with books because of coldness because I did not have gloves.

Photograph 1

The walking trail as used during primary school education

(https://twitter.com/tzaneenv/status/1362664336335003651)

When I was in Grade 7, I moved to stay with my paternal grandmother and my siblings in another village called Bhokwe (Vryheid town). The school was about ten minutes' walk from home but I was only in this school for Grade 7 as it is a primary school. My secondary schooling (Grades 8-12) was another 8-10 km walk. Grades 8 and 9 ignited my passion for physical science as I enjoyed and performed well in natural sciences in these grades. I then chose physical science at Grade 10 not only because of my passion but also due to its orientation to my proposed science-related careers (medicine, electrical engineering, etc). That is why at the beginning of my Grade 12 year, my physical science teacher pleaded with me to obtain “just 65%” in the subject so that I could apply to study medicine. I was motivated to study hard and achieve the 65% score. Despite the rural contextual challenges I experienced, I achieved an overall performance of over 70% for physical science and then competed for entrance to privileged institutions of higher learning such as the University of the Witwatersrand (Wits). My former high school teachers and I identified our rural space as having its unique and complex challenges but did not see this space as a hopeless space for education.

During my secondary school years, I learnt physical science, including the Electricity topic, theoretically. In my rural school, we did not have a science laboratory or practical work instruments and chemicals. This made it difficult for me to understand, for example, the idea of electric current and its practical application. I always wanted to see the practical application of ‘current’ and because of the water analogy mostly used at school, I thought electric current was something you could see and touch. For that reason, I only made mental pictures of what a fully connected series or parallel electric circuit looks like without having seen one connection. Because I had to pass, I used various textbooks to study the difficult topics more, including the Electricity topic. In our school, we would collaborate with Grade 12 learners from neighbouring schools in studying and practicing by solving problems from previous exam papers to guide our thinking. It is worth mentioning that the Electricity topic and its related concepts was my weakness in high school physical science as a learner. As result, I had concluded while in Grade 12 that I would not be an electrical engineer as I performed poorly in this topic. Interestingly, now I teach electricity-related content with passion and guide both pre-service and in-service physical science teachers on how to teach the topic better to their learners.

Part of what made physical science topics, including the Electricity topic, difficult was the use of the IsiZulu as an instructional language, while secondary schools should use English as the language of learning and teaching (LOLT). Even the assessment was in English. While I understood the teacher during the lessons when using IsiZulu, it was difficult to link the classroom information with what I would read on the science textbooks which was written in English. Even though I managed to pass science in secondary school, I struggled to get the meaning of some English terms from the textbooks (language difficulty) and struggled to understand the scientific content (subject difficulty) which did not make scientific sense at the time.

1.1.2 Teaching and Researching the Electricity topic

The notion of this study‵s rationale in section 1.4 is also informed by my life experiences and schooling experiences, including lecturing, and teaching as well as learning the Electricity topic at university level. The latter was when I did not perform well when learning about the Electricity topic in the first year of my Bachelor of Education (BEd) degree at Wits University. However, when doing my BEd 3rd year, I grasped the concepts of the Electricity topic and then my attitude towards the topic changed as I developed an interest in the effective teaching and learning of the topic. This interest and passion for the Electricity topic further shaped my teaching experience of natural science and physical science during my teaching practical[1]. When doing my teaching practical, I noted that my Grade 8 and 9 learners struggled with electricity concepts in natural science, while similar challenges were observed for Grade 10 physical science learners also. Of concern, was my 2014 teaching practice where I was based in the rural Mpumalanga Province (May 2014) and rural KZN Province (September 2014). These schools‵ contexts demonstrated an additional challenge for me as there were no science laboratories or science chemicals and apparatus available at the schools to help present concepts visually for enhanced learner understanding. I then needed to be creative to effectively teach the Electricity topic among other topics. This inspired the current study to explore how teachers teach the Electricity topic in their rural school contexts.

Beyond teaching experience, I have also tutored and lectured at Wits University on the Electricity topic for the 1st and 3rd year undergraduate pre-service teachers including at BEd Honours level for in-service physics teachers[2]. After an informal analysis of my students‵ performance on Electricity content courses, students indicated lack of effective teaching of the Electricity topic from their high school experiences. Also, while lecturing, I conducted my Master‵s in Education (MEd) research with rural schools in Mpumalanga Province where I felt the need to investigate how teachers teach in rural areas of South Africa. This informed the conceptualisation of the current study. After reflecting on my learning, teaching, and lecturing experiences of the Electricity topic, the focus of my PhD research became apparent.

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[1] As part of the Bachelor of Education degree curriculum at Wits University, pre-service teachers are required to do a six-week teaching practical each year. Thus, for the 2012-2015 academic years, I taught physical science in various schools from different contextual environments (rural, township, and urban schools).

[2] Pre-service teachers are the Bachelor of Education students who have not completed their teaching studies, while in-service teachers are qualified teachers who are already teaching in the schools.

1.2 Background of the study

Science and mathematics are viewed as some of the key subjects, including languages, in redressing the past inequalities in South Africa (Gardiner, 2008; Msila, 2007; Spaull, 2013; Mbhiza, 2017), because Black African learners[3] were discouraged from studying the two technical subjects pre-1994. This is one of the reasons the post-apartheid government focused on empowering learners, regardless of their racial and gender background, to confidently take science in schools (Carrim & Soudien, 1999; Msila, 2007; Mbhiza, 2021). Without overlooking the South African government‛s efforts, issues of access to quality science knowledge continue to be a challenge in rural science classrooms, if the provision of resources, appropriate science laboratories and well trained science teachers are taken into serious consideration (Gardiner, 2008; Legari, 2004; Nkambule, 2022). Researchers are concerned with the continuous marginalisation of rural schools, because rural science classrooms continue to be under-resourced with insufficient teaching and learning resources, lack of science laboratories and libraries, and understaffed with a relatively high numbers of un/under-qualified teachers to teach science, mathematics, and technology (Gardiner, 2008; Hlalele, 2012; Masinire, 2015; Nkambule, 2017). Given the challenges with resources, teachers are the main source of developing and ensuring learners‛ access to scientific knowledge, making it important that they are well qualified and proficient in science teaching (Legari, 2004; Roth, 2014 Oyoo, 2017; Zulu, 2018).

It is important to recognise that science teachers communicate physical science concepts and apply multiple approaches to enhance learners‛ learning, such as metaphors, demonstrations, and hands-on practical work to flesh out abstractions (Matthews, 1998; Tsakeni, 2017). While this is the case, several factors have been found to influence physical science teaching and learning in South Africa, which contributes to the reported poor performance in physical science in the country. These factors include ineffective teaching strategies and poor teachers‛ content knowledge, the availability and appropriate use of science laboratories or resources (for practical work), and the influence of language, which is often overlooked by teachers (DBE, 2018; Mji & Makgato, 2006; Oyoo, 2017). Furthermore, the South African Department of Basic Education recognises that failure in the Electricity topic is caused by "a lack of emphasis on practical work and an inability to solve problems that require learners to integrate knowledge learnt in different sections of physics (within physical science), for

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[3] Due to different meanings attached to Black during apartheid, **―Black**s in this study refers only to Black Africans.

example, mechanics with Electricity" (DBE, 2017, p. 180). The DBE has highlighted a need to use macroscopic and symbolic representations (practical work) when teaching the Electricity topic, and for teachers to be cognisant of curricular saliency (CSA), including concept linking. To exemplify curricular saliency issues and a need for link-making to promote continuity, the DBE argues that learners fail the Electricity topic partly because they struggle to identify and label all the forces acting on objects, as well as to connect ideas learned under Newton's Laws with electrostatics (DBE, 2016). This reflects poorly on the teachers‘ understanding of curriculum significance and whether or not they link concepts and topics within the physics domain.

Though practical work is among the recommended teaching approaches for the Electricity topic, most township and rural schools are still without functional science laboratories. It is a dire situation in most South African rural schools, as they continue to be marginalised by the government and education science researchers, like that observed in rural parts of Turkey by Erol et al. (2016). With this context in mind, this study sought to examine how Electricity topic is taught in rural South African schools, considering the identified challenges and difficulty with this topic in physical science. Researchers (Heeralal & Dhurumraj, 2016; Petrus, 2018) have associated poor performance in physical science with the teachers use of outdated teaching strategies such as chalk and talk, rote learning and textbook only, instead of supplementing it with demonstrations and investigative lessons. Without overlooking the critique, while some teachers use resources from the rural context to teach some physical science concepts and topics, they must rely on chalkboards and textbooks. Rural schools continue to be marginalised in South Africa where teaching and learning are concerned; even township schools are in a better position, due to their location in relation to institutions of knowledge like universities. It was therefore important to interact with the teachers by observing their approaches and to understand reasons for chosen approaches to the Electricity topic teaching. This was done because of the gloomy picture of Electricity topic teaching and learning in literature.

1.2.1 Understanding the state of the Electricity topic in physics education

There is a general concern from researchers (Hlabane, 2016; Kibirige & Modjadji, 2022; Ogegbo et al., 2019; Ramdas & Yashoda, 2020) that enrolment in physical sciences continues to be low, due to learners‘, students‘, and teachers‘ perceptions that the subject is difficult to teach and learn. The difficulties and concept confusion in physics, including the Electricity topic, are some of the reasons fewer learners choose physical science in South African schools, and further influence low students enrolment in physics at university level. The physics section, particularly the Electricity topic, has been painted as the most conceptually demanding topic in physical science (Department of Basic Education [DBE], 2018, 2019). Similarly, Mbonyiryivuze et al. (2019) contend that Electricity is one of the most challenging topics to teach learners, because of its abstractness and the concept confusion associated with this topic. Notwithstanding the difficulties, the Electricity topic is among the important topics in physical science in the South African curriculum. This is because of its early association with the objectives and content of science curricula for compulsory teaching and learning in the Intermediate and Senior phases[4], and its importance in the physical science curricula in the Further Education and Training phase[5] (FET) (DBE, 2011; Melo-Niño et al., 2017). The scope of Electricity topic was limited to the concepts in Table 3 for this study.

If the Electricity topic is considered fundamental to most current and emergent technologies (electronics, power generation, sensors), as argued by Kola (2017), it is important to explore teachers‘ approaches to the topic in rural secondary schools. The electricity concepts are prerequisites in the transition of learners understanding from classical to advanced modern physics, making the topic fundamental for the comprehension of physics. It is thus understandable that the topic enjoyed at least 47% of physics questions in paper[6] 1 of the Grade 12 physical science final examination in the South African National Senior Certificate (NSC) prior COVID-19 (DBE, 2018). Despite the higher percentage allocation in the examination, South African learners continue to experience conceptual misunderstanding, which Caleon et al. (2017) link to learners‘ perceptions of the difficulty in learning and understanding the Electricity topic and its related concepts. It is because of such perceptions that exploring teachers' pedagogical practices and pedagogical reasoning becomes important, because of the dearth of classroom-based research in rural secondary schools in South African.

[4] For both intermediate and senior phase, this is where, among other subjects, learners do a combination of life sciences and physical science under the banner of natural sciences (NS). Some aspects of Technology are added in NS for the intermediate phase. Intermediate phase is from Grade 4-6, while senior phase is from Grade 7-9.

[5] **Further Education and Training phase**[5] (FET) is Grade 10-12 level in the South African schooling system. This is where learners specialise in their subject of choice, with physical science being one of the subjects of choice from Grade 10 (DBE, 2011).

[6] In South Africa, physical science is taught as a combination of chemistry and physics from Grade 10 to Grade 12. Even in the National Senior Certificate examination (NSC), learners write a separate physics paper (paper 1) and chemistry paper (paper 2).

According to Ramma et al. (2014), the Electricity topic is also challenging for physical science teachers, because it requires the display of high content knowledge (CK) and pedagogical content knowledge (PCK). It further requires teachers‘ understanding of electricity concepts and laws, their application in specific contexts within the topic, and explicit link-making with other topics in physical science. In essence, teacher knowledge of the topic and how they sequence the concepts of Electricity topic is important when teaching a topic. Therefore, this study sought to unearth and understand Grade 10 rural teachers‘ approaches to the Electricity topic in Vryheid schools, and teachers‘ pedagogical reasoning using classroom observation and video-stimulated recall interviews.

1.3 Problem statement

According to the Trends in Mathematics and Scientific Study (TIMSS), South African learners continue to perform poorly in science and mathematics, as the 2019 results show (TIMSS, 2019). The United Nations Educational, Scientific and Cultural Organization (UNESCO) (2017) posits that South Africa is ranked 140th out of 144 countries for its overall quality of education, and 143rd for its science and mathematics education. Also, it was concerning that South Africa ranked worst in a poll of 62 nations (among which were Bangladesh, Kenya, Tanzania, and Colombia) to evaluate the quality of science and mathematics education in schools (UNESCO, 2017). This indicates that South Africa continues to have a poor average performance in physical sciences relative to other nations, especially as the TIMSS (2019) reports that South African learners continue to fall behind other nations in Africa, Asia, and Europe. The poor performance of South African learners in physical sciences is also reflected in the National Senior Certificate (NSC) test results, which indicate a low level of academic accomplishment in the discipline. The South African performance in science and mathematics in international standards paints a gloomy picture about the quality of science and maths in South Africa, which then questions what and how science and maths are taught in South Africa.

Furthermore, for the years 2017-2022, Grade 12 physical science learners have failed to achieve at least a consistent average performance of 50% in the content[7] related to the Electricity topic in the national examination (see Table 1) (DBE, 2019; 2022). The poor performance of Grade 12 learners in physical science (DBE, 2022) brings into question the

[7] Content related to Electricity refers to questions on Electrostatics and Electric circuits in Table 1.

quality of physical science teaching, teachers‘ teaching strategies during the science lessons, and teachers‘ pedagogical content knowledge in South Africa.

Table 1

Summary of Grade 12 learners' performance in Physical science from 2017-2022 (DBE, 2022)

YEAR	Physical science pass rate (30% and above)	Physical science pass rate (40% and above)	Electrostatics (%)	Electric Circuits (%)
2017	65.1%	42.2%	44.5%	49%
2018	74.2%	48.7%	42%	39%
2019	75.5%	51.7%	49%	53%
2020	65.8%	42.4%	55%	48%
2021	69.0%	44.8%	55%	39%
2022	74.6%	49.7%	41%	41%

Table 1 summarises the observed trends in Grade 12[8] Electricity-related contents in physical science performance for the years 2017-2022. The NSC results for physical sciences revealed that the subject is in grave jeopardy owing to a precipitous decline in the performance of learners on Electricity-related questions. Although the results are for Grade 12, they address the on-going national performance crisis, which is potentially from the Grade 10 teaching and learning of the Electricity topic and related concepts (Spaull, 2013). Table 2 shows a 4-year learner performance in physical sciences for the periods 2019-2022, specific to the selected schools in this study.

Table 2

Grade 12 physical science learners' performance in selected schools (DBE, 2019 - 2022)

YEAR	Sakhisizwe[9] HS (30% and above)	Zabalaza HS (30% and above)	Siyaphumelela HS (30% and above)
2019	88.9%	33.3%	66.7%
2020	80.0%	72.2%	40.2%
2021	78.3%	36.0%	50.0%
2022	95.5%	44.4%	54.1%

Note: HS stands for High School

[8] I am using the information on Grade 12 performance because in the reviewed literature there was no published information on Grade 10 physical science performances. However, Grade 12 information reflected poor foundations of scientific knowledge and principles, which was meant to be established in Grade 10.

[9] Sakhisizwe, Zabalaza and Siyaphumelela high schools are pseudonyms for schools worked with in this study and are detailed in Chapter 4.

Table 2 demonstrates the varied physical science performance for learners performing at 30% and above among the three schools selected for this study located in one rural region under the Zululand Municipality (Vryheid town), KZN Province, South Africa. Moreover, there are concerns about inadequate learner conceptual understanding of science and the Electricity topic in particular, because of the inefficient and inexplicit teaching strategies (Petrus, 2018; Planinic et al., 2012). Even though this is the case, it is not yet clear whether and how rural physical science teachers use inefficient and inexplicit teaching strategies. In essence, the nature of rural teachers' teaching strategies for Electricity topic are absent in science education research; hence, the current study interacted with the teachers to gain insights into their classroom practices.

Furthermore, Ndlovu (2017) argues that lecture style is less time-consuming than practical work, allowing teachers to cover or complete the course on time. Ng and Leicht (2019) concur with Ndlovu and explain the reasons physical science teachers do not do practical work, stating that the lack of laboratory equipment frustrates some science teachers. Ng and Leicht further note a shortage of professional development seminars, to empower teachers to do practical work, and overcrowding is another challenge in some science classrooms, yet real work demands enough space. Therefore, those teachers who do teach practical work only do so in accordance with the department's directives to meet curriculum requirements (Ng & Leicht, 2019).

There are several teaching strategies or approaches that may be used in various contexts to improve students' comprehension. These methods include demonstrations, practical application, animations, and discovery techniques, which address multi-representations of concepts. Some of the approaches need extensive teacher training and may be costly and time consuming, since they need resources such as teaching aids to use in the classroom. For this reason, it could be difficult to implement all the above-mentioned approaches because the instructional methods need classroom space, which is difficult to find in most South African rural schools due to overcrowding (Ramnarain & Hlatswayo, 2018). Similarly, Adeoye (2010) argues that the predominant use of text and lecture instructional strategy and the difficulty of Electricity language (formal physics language) versus the everyday language of learners, also play various roles in the challenges with physical science teaching and learning.

Moreover, physical science learners have difficulty simplifying circuits; they use and manipulate the parallel resistors formula incorrectly, struggle to differentiate between electromotive force (emf) and potential difference and use incorrect equations and misinterpret questions related to Electricity at Grade 12 level (DBE, 2018). While the DBE analysis reflects on learners‘ lack of conceptual understanding, it implies that teachers need to address the abovementioned challenges which are possibly not well addressed during current teaching practices. Even though there is no National available information about Grade 10 learners‘ performance in the topic, the concerns address the importance of understanding teachers‘ pedagogical approaches to the identified difficult topic in physical science, whose status is unknown in rural schools, especially at Grade 10 level. Additionally, understanding teachers‘ pedagogical practices is premised on the persistent poor performance in the Electricity topic which is possibly due to teachers‘ inadequate grasp of the subject‘s content knowledge and the poor teaching practices of the subject (Adeoye, 2010; Ambusaidi & Al-Farei, 2017).

Given the abovementioned analysis, it is not yet clear whether and how teachers make connections between ideas in the ongoing meaning-making interactions in the physical science classrooms. Therefore, it was important for this study to explore how teachers teach the Electricity topic in rural Grade 10 physical science classrooms. This is because Liepertz and Borowski (2018) posit that "a deeper investigation of the quality of content structure connections is still missing in research" (p. 17). The study acknowledges that the existing studies have been predominantly carried out in townships and urban areas, and findings were generalised to other contexts, irrespective of the contextual differences.

1.4 Rationale

The interest in the context of rural schools is influenced by researchers who observed that rural education is generally under-researched in South Africa (Masinire, 2015; Nkambule, 2017, 2022), particularly science education, which addresses the importance of understanding place-based knowledge. The place-based knowledge for this study addresses rural teachers‘ pedagogical practices for the Electricity topic, which is unmapped in the South African science education literature, despite the continuing learners‘ poor performance in the topic. Therefore, this led to the conceptualisation of this study which aimed to understand whether and how rural place, space, and the nature of rural teacher‘s education and training shape their teaching of Electricity topic. This study is important when considering that rural science classrooms are permeated with teachers who have insufficient physical science training and qualifications (Nelson Mandela Foundation, 2005), as well as the lack of a conducive environment in terms of resources to enhance teaching and learning of physical science including the Electricity topic (Gardiner, 2008; Legari, 2004; Zulu, 2018).

The specific focus on the Electricity topic is based on the topic‘s importance in the physical science curriculum. The topic is introduced at Grade 4 and taught in every grade through to Grade 9 under Natural Science subject. The topic is strengthened and officially introduced for the FET at Grade 10. The topic is given much weight in the Grade 12 syllabus despite poor performance in the topic (DBE, 2011, 2018). Electricity is one of the fundamental knowledge areas of the FET physical sciences curriculum in South Africa (Mavuru & Ramnarain, 2017) as well as being one of the most essential topics in high school physical sciences, carrying a high proportion of marks in the physics examination paper. In the pre-COVID-19 era, the Electricity (and Magnetism) topic constituted 47% of the final physics matriculation examination and currently contributes 36.6% among other three physics topics (DBE, 2021). According to Dhurumraj (2018), learners have a negative image of the physical science knowledge domain because they regard it as an abstract subject that is difficult to grasp. The nature and genesis of learners' conceptual challenges in Electricity may in part rely on teachers‘ incapacity to properly teach ideas linked with this topic (Dhurumraj, 2018). This, in turn, can be attributed to various teacher pedagogies such as teachers' lack of relevant content and pedagogical content knowledge on electromagnetism (Saglam & Millar, 2006); teachers' lack of confidence in science teaching, including in the topic of Electricity (Chen & Mensah, 2018); and teachers' use of traditional teaching methods, such as lecturing only, among other pedagogical challenges.

Despite the teaching of the Electricity topic from Grade 10 level for FET, the diagnostic report from NSC examination indicates that Grade 12 learners still perform poorly in Electricity when compared to other topics within physical science (DBE, 2020, 2021). The learner performance prompted this research to investigate how teachers teach the Electricity topic, considering the learners‘ continual poor performance, as noted in Table 1. While it is not easy to obtain the National learners‘ performance for Grades 10 and 11, the poor performance in the Grade 12 national examination, specifically in the Electricity topic, was of concern. As a former student who studied physics in rural schools, I particularly researched Grade 10 teachers because this grade connects the senior phase and the FET phase, and it is in this grade that teachers should lay a good foundation for physical science concepts, especially the continuous topics like Electricity, given that the topic is also covered in grades 11 and 12.

1.5 Purpose of the study

The purpose of this study was to explore teachers‘ pedagogical approaches during the Electricity lessons in Grade 10 rural classrooms and examine teachers‘ pedagogical reasoning for the observed teaching approaches.

1.6 Objectives of the study

In relation to the purpose, the objectives of the study can be summarised as follows:

a) To describe and critically analyse teachers‘ pedagogical approaches to the Electricity topic in rural physical science classrooms.

b) To gain insights into the teachers‘ pedagogical reasoning for the chosen approaches during the Electricity lessons.

c) To interrogate and discuss the factors that influence the teachers‘ approaches to the Electricity topic in Grade 10 rural classrooms.

1.7 Main research question

The study sought to address the following main research question: ***How do Grade 10 rural physical science teachers teach the Electricity topic?*** To help answer this main research question, three sub-questions were devised and are detailed below.

1.7.1 Sub-research questions

1. What are the Grade 10 physical science teachers‘ pedagogical approaches during the Electricity lessons?

2. What are teachers‘ pedagogical reasoning for the observed pedagogical approaches during the Electricity lessons?

3. What are the factors that influence the teachers‘ pedagogical approaches to the Electricity topic in Grade 10 science classrooms?

1.8 Significance of the study

Given the lack of existing research with physical science teachers in rural South Africa, this study is important to unearth the nature of physical science teachers‘ pedagogical content knowledge on the topic of Electricity including teachers‘ reasoning for enacted pedagogies, and the rural contextual impact on science teaching. Therefore, this study contributes to the understanding of rural teachers‘ pedagogical approaches towards the topic of Electricity, and the factors that influence science teaching in rural South African contexts with the KZN province as a case. The findings of this study also provide baseline data to the few studies examining the teaching of topics like Electricity in South African rural classrooms Furthermore, the findings of this study contributes to the rural place-based knowledge of how teachers teach the Electricity topic in Grade 10 rural classrooms, considering the dominant urban-based education research that has overlooked rural teachers‘ experiences.

National DBE: Rural Education Directorate. The findings of this study on pedagogical affordances and challenges experienced by physical science teachers in rural school contexts will help the rural education directorate to consolidate context sensitive intervention strategies aimed at improving quality teaching and curriculum enhancement within rural schools. The study also provides insights into the limited usage and impact of unavailability of and/or outdated science resources in rural schools, which could be used by the directorate when mobilising and allocating resources aimed at improving the quality and performance of schools in rural areas.

Provincial policy makers. The exposed teacher knowledge of curriculum interpretation, concept overload versus allocated teaching time, and allocation of practical work time in the curriculum, are some of the considerations to be taken by education policy makers. Also, to benefit policy makers, especially with the political agenda of rural education policies in South Africa, this study provides some important pedagogical affordances of the rural spaces which could be officiated in the curriculum towards the conceptualization of rural education curriculum or policy.

Rural secondary and primary school teachers' professional development. The classroom observation and video stimulated recall interview (VSRI) data sets provided information on handling science apparatus (practical work), curriculum interpretations, teacher content knowledge gaps as few considerations for teachers‘ professional development programs. Also, the findings of this study may also benefit science teachers in terms of enhancing tactics for the design of teaching Ohm's law, for example, and boosting learners‘ achievement in the overall topic of Electricity. Good teachers, according to Stephen (2018), possess an arsenal of multiple representations (i.e., analogies, illustrations, examples, demonstrations, and experiments) for describing and structuring a topic to make it understandable to their learners. This was evident in the instruction of abstract Electricity topic. Therefore, this research can provide inadequately equipped science teachers with a powerful collection of multiple representations which in turn could lead to improved physical sciences teaching and learning experiences.

Initial Teacher Education (ITE) Program. The findings of this study can help ITE Program with knowledge about teaching physics in rural secondary schools and how they could enhance their methodology courses for pre-service science teachers. Teacher training institutions may also benefit when designing or modifying their curriculum to consider contextual factors that enhance and/or impede the delivery of quality and effective teaching of physical science, including the topic of Electricity, in rural classrooms of South Africa.

1.9 Operationalisation of terms

Rural:

The operationalisation of the term rural for this study was informed by the classifications of urban and rural spaces in South Africa, even though these terms may be conceptualised differently in other countries (Gardiner, 2008). Generally, rural areas are defined according to the place of residence and the type of jobs residents engage in, without placing emphasis on the individuals within a particular rural space (Gardiner, 2008). This study, however, acknowledges the complexities in defining rural. Notwithstanding these difficulties, a working definition of rural for this study is complex, dynamic, and shaped by a wide range of factors, including peoples lived experiences within a rural space (Balfour et al., 2008; Nkambule et al., 2011). Therefore, this study conceptualised rurality as a dynamic context where lived experiences of individuals and social issues are related to the rural context (Nkambule et al., 2011). This understanding of rurality ascribes to the idea of space which sustains human existence and development outside the jurisdiction of metropolitan / city /

town authority (Masinire et al., 2014). As such, rural spaces should be viewed according to the lived experiences of individuals and as being unique to specific locations and time.

Teaching Approaches

Researchers define teaching approaches in many ways. In some definitions, approaches are referred to as teaching strategies. This study understands and uses teaching approach and teaching strategies synonymously. Zohud (2015) views teaching approaches as the techniques that teachers use in the classroom to help learners learn and to participate in class. Similarly, Jordan and Adrienne (2004) define teaching approaches as the techniques that can be used across curricular areas to support the learning. While this is the case, Wandberg and Rohwer (2009) foreground the structure, system, methods, techniques, procedures, and process that a teacher uses during instruction, in their definition of teaching approaches. All these definitions have value in the conceptualisation of teaching approaches and all informed teaching approaches as understood in this study.

Moreover, teacher‘s chosen teaching approaches can help expose that particular teacher‘s pedagogy; Shah and Campus (2021) argue that the term pedagogy has developed to describe the methods and approaches used by teachers to lead learners in their learning. Therefore, I adopt Shah and Campus‘ (2021) description of pedagogy to define teaching approaches as the relationships and interactions between teachers, learners, the learning environment and the learning tasks to help learners learn the topic of Electricity. Bashir et al. (2018) take the idea of pedagogy further by describing it as subject-matter knowledge and strategies that lead to measurable outcomes in learners’ knowledge. This is the teacher’s mastery of a particular subject as well as the most effective ways to teach it (Bashir et al., 2018). In light of the abovementioned definitions, I therefore defined teaching approaches for this study as teachers‘ techniques of presenting the subject matter knowledge in the most effective ways of teaching, including providing opportunities for interactions between the teacher, learners and the learning environment, together with the learning tasks, to enable deep understanding of Electricity topic.

1.10 Outline of thesis chapters

This thesis has a total of ten chapters. The first chapter provided the background for the study, highlighting the need to understand the teaching of physical science in rural schools, in particular the teaching of conceptually demanding topics such as the Electricity topic. The chapter addressed the importance of this research and demonstrated that the quality of rural education in South Africa is doubtful owing to the low physical science pass rates. While this is the case, poor performance associated with the topic of Electricity has been noted in physical science. Despite poor performance, science education research remains mute on physical science teachers' pedagogical strategies for the topic of Electricity. Due to the minimal study attention devoted to this field worldwide, regionally, and locally in South Africa, silent concerns about physical science teaching in rural regions remains in the periphery of science education research agenda. Even though, physical science is argued to be a key subject in addressing issues of social justice, equality, and change. This illustrates the significance of teacher comprehension of the nature of physical science, the scientific information acquired by teachers, and the way they convey this knowledge. The importance of getting the fundamentals of physical science, including Electricity, correct in Grade 10 classrooms is emphasised, as solid foundations influence Electricity learning in later grades, which in turn contributes to the observed poor performance in physical science, including in Electricity, in Grade 12.

In Chapter 2**,** I present a review of literature on the teaching of physical science. Attention is given to teaching the topic of Electricity. In this review, the nature of science and the role of the science teacher are highlighted. The chapter further presents debates about teaching and learning physical science in rural contexts, with an emphasis on South African rural contexts. Physical science content knowledge is at the centre of these debates, where I focus on its importance and the challenges it poses to learners and how teachers should approach its teaching. The chapter also highlights the complexities in defining rural and rurality in relation to the state of rural education research (internationally, regionally, and locally), and the contextual difficulties that science teachers encounter when teaching physical science in South African rural schools.

Chapter 3 discusses the theoretical underpinning for the study. Topic-specific Pedagogical Content Knowledge (tsPCK) and Pedagogical Link-Making (PLM) are discussed individually and jointly. Each framework is well justified in its use, and the complementary nature of these frameworks are discussed in this chapter. The chapter advocates for the useful relationship between tsPCK and PLM for the comprehensive understanding and analysis of physical science teachers‘ pedagogical approaches in rural classrooms including teacher pedagogical reasoning.

In Chapter 4, I present in detail the research process and methods that were used in generating, organising and analysing the qualitative data sets for this study. Each process is justified for relevance in the study. The chapter provides an overview of the study with the presentation of the chosen research paradigm, and how it informed the research design, research approach and, in turn, the methods of data generation, including the analysis process. Additionally, I also discuss the sampling technique and a justification of the sample size.

Contrary to traditional thesis writing styles, Chapter 5 presents the analytical framework of the study. In this chapter, I focus on the analytical language for the study which in turn led to the development of an analytical framework for the study. This analytical framework is then discussed in terms of how it was used in analysing the data for this study. Different components of the conceptual and theoretical frameworks are brought together to form a practical analytical framework. Examples of how data were analysed in relation to the analytical framework are also presented in this chapter.

In Chapters 6, 7, and 8, I present and analyse primarily classroom observation data and video-stimulated recall interview data in light of the identified conceptual, theoretical and analytical frameworks to expose teachers‘ pedagogical practices for the Electricity topic. Since this is a case study, each teacher‘s data is presented in a separate chapter, hence the three chapters for three teachers. In each chapter, I focus on observed classroom teaching episodes because of their integrated ways of showing tsPCK components and the teacher‘s attempts to make pedagogical links to build scientific knowledge of the topic of Electricity. Therefore, Chapter 6 presents and analyses the first teacher‘s pedagogical practices from the observed classroom teaching. Chapters 7 and 8 detail the second and third teachers‘ pedagogical practices respectively.

Chapter 9 presents the discussion of findings in an integrated format. This chapter is called a cross-case discussion because the observation data, interview data and video-stimulated recall interview (VSRI) data for the three teachers are discussed relationally in light of the reviewed literature, and the study's theoretical and conceptual frameworks. The discussion is also informed by the study purpose and research questions asked in section 1.7. As such, themes were developed to structure this chapter.

Finally, Chapter 10 is the concluding chapter. In this chapter, I present a summary of the study's findings and propose directions for future research in relation to the discussed findings from Chapters 6 to 9. This chapter also focuses on the implications of the findings and my reflections of rural teachers' pedagogical practices for the topic of Electricity.

CHAPTER 2

Teaching the Electricity topic in South African rural schools: A literature review

"Foremost among the challenges facing rural South Africa is the task of improving the quality of education" ~ Nelson R. Mandela (Nelson Mandela Foundation, 2005, p. vii)

2.1 Introduction

The above quotation was made in 2005; 18 years later little has changed for South African rural communities and rural education. The quotation further demonstrates a long overdue interrogation of rural education aiming at improving the quality of teaching and learning, and to address inequality and social injustice. As mentioned in Chapter 1, physical science is among the most poorly performed subjects in the South African curriculum, contributing immensely to the questioned quality of education in the country generally, and specifically the rural parts of the country. The outcry is not only unique in South Africa; there is also on-going distress regionally and internationally about the appalling state of physical science teaching and learning (Bilbao-Osorio et al., 2014; DBE, 2021; Namugaya & Habumugisha, 2017; TIMSS, 2019; Tsakeni, 2018), and this challenge seems to be acute in rural and farm schools (Bloch, 2008; Paxton, 2015; World Bank, 2015; Zulu, 2018).

There are various factors that contribute to the atrocious state of physical science teaching and learning, and these include teachers' pedagogical approaches as the most important tool in the classrooms to promote intellectual quality (Erol et al., 2016). In light of the abovementioned considerations, this chapter discusses the teaching and learning of physical science, with a focus on the topic of Electricity. Challenges associated with the teaching of physical science, including the topic of Electricity, are also highlighted in this chapter. Literature on the state of teaching physical science in rural schools internationally and locally, focusing specifically on Electricity topic, is reviewed. The chapter also discusses studies that have focused on rural place-based education research, by using the teaching of Electricity topic as a case.

2.2 The nature of physical science as a subject

It is important to locate physical science within the context of science as a discipline, to locate and understand the nature of science education. The nature of science (NOS) refers to the *body of knowledge*, a *method*, as well as *way of knowing* (Lederman et al., 2013; Sumranwanich, & Yuenyong, 2014). According to Akarsu (2017) and Sumranwanich and Yuenyong (2014), the science community agrees that science is tentative, subjective, empirically based, socially embedded, and dependent on human imagination and creativity. Thus, science teachers do not have to teach only laws, theories, and facts but also scientific processes that the scientifically literate person should understand, while also being cognisant of the relationships between science, technology, and society. Within the context of NOS, Hubber (2018) posits that the subject of physical sciences is considered important as it underpins the economic growth of a nation as a crucial component in the creation of most contemporary technologies. Electricity and Magnetism as a science theme is largely responsible for the creation of contemporary technologies, and physical science teachers need to appreciate the alternative perspective to what is known of science and find creative ways to enculturate learners into this discourse. Enculturation means science teaching should be about transforming scientific knowledge, skills, values, and attitudes to learners, and bringing the abstract concepts to more concrete and comprehensible forms for learners' knowledge-building and deep understanding.

Furthermore, physics and some fields of mathematics are part of a natural philosophy that has made important contributions to contemporary civilization via breakthroughs resulting from conceptual advancements over the last decades (Preston, 2017). Physical science, according to Hubber (2018), connects mathematical knowledge to real-world applications and should enable learners to understand more coherent and practical problem-solving strategies, thus obtain a fresh appreciation for the world around them. Physical sciences use mathematical ideas and procedures in their laws. It is often believed that mathematics is the language of physical scientists, particularly physicists (Hubber, 2018). This could explain the reason the observed teachers in this study mostly used symbols and calculations while teaching the Electricity topic and related concepts, representing the relationship.

2.3 Teaching and learning physical science: General education perspective

While the study focuses on the teaching of the Electricity topic, it is important to present a brief discussion about the teaching and learning of physical science and where the topic is located within the subject. Following from this section is the overview of the Electricity topic in the science curriculum, as the focus of this study. Firstly, teaching is a complex process, and it is viewed differently by different scholars. Condy and Phillips (2020) perceive teaching as a complex and multi-dimensional process requiring deep knowledge and understanding in a wide range of areas. Sequeira (2012) defines teaching as a set of events, outside the learners, which are designed to support the internal process of learning. The set of events should involve demonstrations or classroom talk that takes place between teacher and learners and occurs during certain definable activities (Rajagopalan, 2019). This process is defined by Shulman as instruction and refers to the "management, presentations, interactions, group work, discipline, humor, questioning, and other aspects of active teaching, discovery or inquiry instruction, and the observable forms of classroom teaching" (Shulman, 1987, p. 15).

Secondly, in the context of teaching, the teacher has a significant role to play. According to Sequeira (2012), the traditional role (teacher-centered) or the modern role (facilitator) are often observed in classroom teaching even though some teachers could display both elements of traditional and modern roles simultaneously. Despite a chosen role for teaching, it is important to note that learning increases when the teacher builds on the previous experience of the learner. This means that for effective teaching, pedagogical links have to be made for knowledge building purposes and for continuity and concept progression (Scott et al., 2011), especially when considering learners' prior knowledge (LPK). Therefore, quality and effectiveness of teaching is argued to be influenced by teacher professional knowledge, which consists of content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of educational contexts, insights into how learners learn, and knowledge of educational ends, purposes, and values, and their philosophical and historical grounds (Condy & Phillips, 2020; Shulman, 1987). Additionally, like many scholars, teaching is regarded as both an art and science (Marzano, 2017; Weisman, 2012). As an art, teaching emphasises the imaginative and artistic abilities of the teacher in creating a worthwhile situation in the classroom to enable learners to learn, while as a science, teaching sheds light on the logical, mechanical, or procedural steps to be followed to attain an effective achievement of goals (Rajagopalan, 2019). Both the art and science are observable during classroom interactions and further exposed through teachers‘ pedagogical reasoning.

Furthermore, the teaching and learning of physical science encompasses building knowledge about the NOS and requires the active involvement of learners and their ideas (often everyday concepts) in the meaning-making process alongside the ideas proposed by the teachers (science concepts) (Lehesvuori & Ametller, 2021; McComas, 2014). Additionally, teaching physical science also involves introducing learners into the world of ideas and concepts, and an understanding of the interconnectedness of the science concepts and topic, which requires teachers and learners to make a paradigm shift from explaining the everyday world towards scientific-based reasoning (Lehesvuori & Ametller, 2021; Scott et al., 2013; Sumranwanich & Yuenyong, 2014). This means that for physical science teachers to enculturate science learners to the science discourse and develop deep understanding of physical science knowledge, they need to have a unique knowledge base (teacher professional knowledge and skills) that assist with designing and executing lessons effectively and efficiently (Stender et al., 2017). Shulman (1987) conceptualises the knowledge base as PCK, and teachers should transform the discipline knowledge they possess into forms that are pedagogically powerful.

The above discussion addresses teacher knowledge which shapes their teaching approaches. Teaching approaches are defined differently by researchers. Zohud (2015) views teaching approaches as the techniques that teachers use in the classroom to help learners learn and participate in class. Similarly, Jordan and Adrienne (2004) define teaching approaches as the techniques that can be used across curricular areas to support the learning of learners. While this is the case, Wandberg and Rohwer (2009) foreground the structure, system, methods, techniques, procedures, and process that a teacher uses during instruction, in their definition of teaching approaches. The abovementioned definitions highlight techniques that teachers use to support learning, and that teaching must be structured and systematic for learners to experience knowledge building. For Preston (2017), it is problematic for physical science teachers to have a firm grasp of the discipline‘s content and theory but lack the communication skills (teaching approaches) necessary to impart this knowledge to the learners. Aboagye et al. (2018) and Kind (2014) caution that science teachers should not only be content specialists but must be able to transform the content knowledge into forms that are pedagogically powerful and efficient. It is therefore important to gain insight into the physical science teachers‘ approaches during the Electricity lessons, due to the dearth of research, particularly from the rural classrooms, because the existing research is dominantly urban based.

2.3.1 The complexity of teaching physical science in rural schools

Before I engage with the discussion in this section, it is worth noting that defining the term rural is still a highly contested task in research and policy, within and across countries, due to the complexity and dynamics of rural areas, especially in South Africa (Nkambule & Mukeredzi, 2017; Putri et al., 2022). Gopaul (2009) and Statistics South Africa (2003) describe rural areas according to the type of land use (commercial farming), where people farm or depend on natural resources, including the villages and small towns scattered across these areas. This understanding presents a deficit paradigm of rural and rural people, and Moletsane (2012) suggests a move beyond this deficit paradigm and raises questions of whether all rural areas are about farming and/or rural resources. The abovementioned rural descriptions disregard the lived experiences of individuals within and across rural spaces. The descriptions also lack acknowledgement of the distinctiveness, agency, and strength of rural communities since Masinire et al. (2014) and Maringe et al. (2015) suggest an acknowledgement of these factors when describing rural areas and rural people. Therefore, this study conceptualises rurality as a dynamic context with lived experiences of individuals, and social issues that are related to the rural context (Nkambule et al., 2011). The conception is informed by Moletsane‘s (2012) suggestion to encourage rural education scholars to acknowledge the challenges faced by rural communities but also to recognise the individual‘s agency within these spaces.

Teaching physical science within the context of rural education is a challenge when considering that most rural South African schools are characterised by dilapidated infrastructure, overcrowding, lack of chalkboards, insufficient textbooks, and lack of functional science laboratories, among others, which hamper teachers‘ working conditions and constrain their teaching (Nkambule, 2022). And considering physical science as a practical subject (DBE, 2011; Oyoo, 2012), practical work becomes an essential aspect in the teaching of the subject for development of deep conceptual understanding (Kibirige & Maponya, 2021). Nevertheless, the availability of physical science apparatus for practical work is unfortunately scarce for many South African rural schools (Gardiner, 2008; Mtsi & Maphosa, 2016; Ramnarain, 2014). This possibly has undesirable consequences or implications for the teaching and learning of abstract physical science topics such as Electricity, which need visuals (hands-on activities) to show ideas of charging including flow of charges, induction, potential, series and parallel connections and operations of electric circuits, to mention a few. The existing teaching and experiment resources are insufficient for the learners to comprehend science knowledge by themselves and require teachers to stand in front of the classroom or laboratory during demonstrations.

Authors (Gardiner, 2008; Nkambule et al., 2011; Ramnarain, 2014) have noticed that rural schools where science laboratories are available have been mostly used as storerooms or additional classrooms instead of operational science laboratories. This is due to a lack of materials inside the laboratories and schools eventually use them as extra classes rather than leaving them empty (Nkambule & Mukeredzi, 2017; Zulu, 2018). Almost three decades since Muwanga-Zake (1998) noted that “most of the scientific approaches and content favors urban settings more than rural settings” (p. 150), little has changed after 29 years of democracy in South Africa. The change appears symbolic for rural schools because the National Department of Education built the laboratories without equipping them with proper resources to promote practical work in science. These schools are unable to raise funds and equip the laboratories, because most community members work on the farms and earn little salaries. Hence, these schools are no-fees schools, because the government realised parents‘ inability to afford school fees.

Moreover, in science, practical work plays a major role in effective teaching and learning, which means some teachers might not engage with such an important practice of the subject in rural schools. In addition, a general shortage of qualified science teachers in Africa, including South Africa, has been identified (Kola, 2013; Muwanga-Zake, 1998), and this shortage is acute in rural schools (Gardiner, 2008; Legari, 2004; Zulu, 2018). As mentioned earlier, newly qualified teachers do not want to teach in rural schools, resulting in insufficient qualified science teachers, while experienced teachers leave the rural schools to urban areas, causing brain drain. The existence of unqualified and underqualified science teachers in South Africa has also been noted by Ogunniyi and Rollnick (2015) and Mtsi and Maphosa (2016), and its impact on science teaching, especially in rural schools, is not well known.

2.4 The Electricity topic in science curriculum

Rural, urban and township schools operate under one curriculum, the Curriculum and Assessment Policy Statement (CAPS), to universalise education in South Africa. The universalisation of the South African curriculum across all public schools could represent social injustice for rural schools and a contributory factor to the poor understanding of physical science knowledge, considering the contextual difference that disadvantages the teaching and learning of the subject. Rural physical science teachers, like other public-school teachers, work extensively with CAPS (DBE, 2011), regardless of their often overlooked contextual challenges (Gardiner, 2008; Legari, 2004). As mentioned earlier, some of the challenges include, but are not limited to, lack of functional science laboratories, shortage of textbooks, lack of learner proficiency in the language of learning and teaching (LOLT) which is English, underqualified, and unqualified science teachers, among others (Gardiner, 2008; Mweli, 2017; Zulu, 2018).

Additionally, unlike other Southern African Development Community (SADC) countries like Tanzania and Zimbabwe, where physical science is taught as two separate subjects: physics and chemistry (Meana, 2009; Ncube, 2014), South Africa teaches school science as a combination of chemistry and physics (DBE, 2011). Even in the NSC examination, learners write a separate paper 1 (physics) and paper 2 (chemistry) (DBE, 2021). The amalgamation of chemistry and physics could be another factor for the overall poor performance and low status of physical sciences because some learners may be stronger in one component, like physics, and weaker in another component, like chemistry (Ncube, 2014). Moreover, Molele (2017) emphasises the necessity of paying greater attention to the facilitation of physics for all learners, since relevant skills are required in a technologically advanced and labour-intensive environment. Therefore, South Africa cannot afford to continue having learners that performs poorly in physical sciences, as it affects the number of students that major in science at school and tertiary institutions. The curriculum for physical sciences includes six major areas of knowledge: Matter and Materials; Chemical Systems; Chemical Change; Mechanics; Waves, Sound and Light; and Electricity and Magnetism opportunities (DBE, 2011).

Until the advent of the Coronavirus disease (Covid-19), the Electricity and Magnetism[10] knowledge area combined the sections of Magnetism and Electricity in the Grade 10 CAPS document. However, due to Covid-19, the curriculum was streamlined, and the Magnetism section was removed in 2020 from the Grade 10 syllabus until the year 2024 (DBE, 2021). Notwithstanding the situational change, the combination of Electricity and Magnetism is still regarded as a core issue in the general science and physics curriculum at all schools and university teaching levels. When the section is returned in 2024 (DBE, 2020), it is still essential that science teachers teach this knowledge area in effective ways that will enable learners to grasp the fundamentals of both the Electricity and Magnetism phenomena (Ramnarain & Hlatswayo, 2018).

Furthermore, the Electricity topic is extremely complex and difficult to comprehend, including in the rural schools. Although learners in urban and township schools have places like universities and the Sci-Bono Discovery Centre[11] to attend for extra classes, especially for practical work, rural learners do not have such alternative places because universities are located far from the rural schools for epistemological access. This is one of the reasons teaching and learning in rural schools is the issue of social justice if South Africa wants to ensure equity and quality education in such schools. Though the Electricity topic is challenging, it is important in the physical science curriculum to introduce learners to the various scientific skills as early as possible, given that the topic is covered from Grade 5 until Grade 12 in CAPS. These skills include “classification, interaction, quantification, designing and investigation, drawing and assessing conclusions, model formulation, hypothesis formulation, identification, and control of factors, predicting, acquiring, inferring, manipulating, problem-solving, explanation, reflective, noticing, institutional, and comparing skills” (DBE, 2011, p. 8). It is imperative for the teachers to seriously consider these skills when planning and teaching physical science topics, including the Electricity topic.

[10] This study initially focused on the teaching of Electricity and Magnetism. However, data gathering on the Magnetism section was not complete when the South African government decided on a streamlined curriculum that saw Magnetism phased out of the Grade 10 level for 2021-2024 academic years due to Covid-19 demands. Due to this, the current study was then refocused on the Electricity topic instead of both Electricity and Magnetism. This does not mean that ideas of Magnetism are no longer important; in fact, Magnetism still enjoys a greater percentage of the physics curriculum in Grades 11 and 12.

[11] The Sci-Bono Discovery Centre is an independent non-profit company which is a world-class science centre located in Johannesburg, South Africa. Sci-Bono‘s goal is to promote interest in and enjoyment of all aspects of science and technology by offering school learners, educators and the general public the opportunity to engage with its collection of hands-on exhibits and displays and to participate in a wide variety of science-related events and activities (Sci-Bono Discovery Centre annual report 2020/1).

As mentioned above, the ideas of Electricity topic are introduced as early as Grade 5 in the South African science curriculum. These ideas are developed in the subsequent grades until they are officially introduced for the FET phase in Grade 10 when learners specialise in the physical science subject as one of the major subjects. Moodley (2013) argues that the CAPS document shows the progression of the Electricity topic by introducing energy and change; and energy systems and conversions at early grades which are then further developed from Grade 10 to 12. Though the topic is developed from Grade 5 (see Table 3), it is argued that natural science teachers often overlook this topic mainly because they are not trained to teach the physical science aspect, including the Electricity topic (Lemmer et al., 2008). Therefore, in Grade 10, learners should have some knowledge about the topic; however, considering the state of teaching in natural sciences, Grade 10 teachers should not take for granted that learners were taught concepts underpinning this topic.

Table 3 demonstrates concepts of cells, batteries, electric circuits, including resistance, which are developed from the early grades. In Grade 10, these concepts are given more time to enable teachers to develop and build learners‘ understanding, as compared to previous grades. Of importance for the teachers is to teach the Electricity concepts and topic effectively and clearly because the Electromagnetism and Electrodynamics in Grades 11 and 12 build from this Grade 10 Electricity knowledge and skills. In Grade 10, learners are taught the concept of electrostatics, charge, potential difference, current and resistance in sequential order. This is an indication that the Electricity topic is developed from lower grades (Grades 5-9) and as expected, becomes complex at secondary (Grades 10-12) and tertiary levels. Considering the early introduction of the topic, it is not expected that learners should experience difficulties with learning the topic, especially if teachers supported knowledge building by explaining the concepts relations and continuations using different teaching approaches.

Earlier, Beaty (1996) mentioned the importance of understanding teachers‘ conception of Electricity, and noted the most used definition as the flowing motion of electric charge. From this definition, an assumption could be made, for example, of the existence of charges, and that they can move together in a flowing motion called a current. Moodley (2013) states that Electricity is explained to children at lower levels in terms of static electricity and current electricity, where the former is caused by the transfer of charges that can be observed as sparks when objects are rubbed together. Later, learners are taught that current electricity results when a battery causes an electrical pressure in a closed circuit. This lays the foundation for the conceptual understanding of a potential difference that must be followed up in higher grades as energy transfer per unit charge to mention an example of how ideas are to be linked from one grade to the next.

Table 3

The development of Electricity topic in the South African science curriculum (DBE, 2011)

Grade	Concepts
5	Cells and batteries – simple circuits; Safety with electricity
6	Electric circuits including circuit diagrams; electrical conductors and insulators; main electricity
7	Potential energy – cell, battery, electrical systems; Energy transfers
8	Static electricity; Energy transfer in electrical systems - Circuits and current electricity; Components of a circuit; Effects of an electric current; Series and parallel circuits
9	Electric cells as energy systems; Resistance; Series and parallel circuits
10	Electrostatics; charge conservation; charge quantization; Electric circuits - emf, potential difference, current, measurement of voltage and current, resistance, resistors in parallel
11	Electrostatics; Electromagnetism - Magnetic field associated with current-carrying wires, Faraday‘s Law; Electric circuits - Energy, Power
12	Electric circuits - internal resistance and series-parallel networks; Electrodynamics - electrical machines; alternating current

2.5 Mapping the teaching and learning of the Electricity topic

It is concerning that learners perform poorly in the Electricity topic because they confuse its concepts with the terminology used in everyday life, and alarmingly, this confusion[12] remains unchanged by teaching (Guisasola, 2014). Likewise, Dega (2012) indicates that learner difficulties in most electricity-related concepts remain the same before and after instruction, which is concerning for this study and points to a need to understand teacher pedagogical approaches used to teach the Electricity topic. Of the reviewed literature (Mbonyiryivuze et al., 2019), most studies have focused on learners‘ understanding of the Electricity topic,

[12] This is where learners confuse the meanings of everyday words that are used as science concepts, for example, words such as Energy, Power, Potential Difference, and Charge (Maloney et al., 2001).

including its misconceptions (Van der Merwe & Gaigher, 2011), while studies on teachers have concentrated on teacher perceptions of the Electricity topic and overlooked classroom teacher practice (Moodley & Gaigher, 2019), despite the difficulties learners find in learning the topic (Melo-Niño et al., 2017).

2.5.1. Teaching and learning of the Electricity topic: International perspectives

The teaching and learning of the topic of Electricity needs representations due to the almost ‘imaginary‘ concepts (ideas) of the topic that have to be linked to make a whole. Though conducted with students at a university level, Narjaikaew et al. (2010) found that students perform significantly better after teaching using demonstrations and visuals to help them infer rules and theories, and when using interactive notes, questions, and discussions to support learning. Similarly, De Carvalho (2019) has found the multisensory approach (diagrammatic symbols, physical components and functions) to have an important impact on England‘s pre-service teachers‘ perceptions about teaching and learning and pedagogical understanding, as well as achieving a more meaningful engagement of learners during and after the lesson, in particular if the teacher is also actively involved in doing the task with learners.

The findings on the multisensory approach are important and could also be applicable to the South African context since the Electricity topic is perceived to be abstract. The effectiveness of this approach remains questionable, especially for most South African rural schools as they continue to be marginalised, under-resourced, and under-researched (Du Plessis & Mestry, 2019; Nkambule, 2022). However, to support visualisations for Electricity teaching, Preston et al. (2022) record that deep learning was evidenced where the Australian teachers guided learners to attend to critical aspects of electric circuits‘ concepts through multiple representations, including correct usage of science language. The multiplicity of representations and their interaction positively enhances understanding, challenges non-scientific views, and promotes scientific models of electric circuits (Preston, 2019). From the international teaching perspectives, there is a need to visually represent the Electricity topic for deep scientific understanding.

The abovementioned visualisations are to flash out abstractions of the topic while helping to dismantle some misconceptions about the Electricity topic and the process of teaching and learning. Regarding misconceptions, Aligo et al. (2021) found that both learners and teachers in the Philippines share some common models of misconceptions about the Electricity topic, like the clashing current, shared current, current flow as water flow, short circuit, and local reasoning models. These are some of the misconceptions to be considered when teaching the Electricity topic. Moreover, Gunstone et al. (2009) established that some Australian teachers perceived Direct Current Electricity as easy to teach even though they also saw it as hard for learners to learn, which shows the complexity of the teaching and learning. Also, some of the teachers revealed their misconceptions and lack of understanding the energy sources in electric circuits in relation to voltage, potential, and emf. Hence, the current study planned to explore how rural teachers perceive and teach voltage, potential and emf among other electricity-related concepts.

Furthermore, the German scholars, Burde and Wilhelm (2020) argue for a need to move beyond traditional teaching for electricity-related concepts and recommend a focus on providing learners with a qualitative understanding of circuit behaviour when the Electricity topic is introduced. Some of the traditional teaching approaches include electric potential in circuits presented as two completely unrelated topics in electrostatics and in electric circuits (Guisasola, 2014). Also, the concept of potential (potential difference or voltage) is often only a secondary consideration in traditional teaching (Burde et al., 2022), and only introduced mathematically without attempting to provide learners with a conceptual understanding of the relationship between potential differences and current. This often exclusively focuses on situations where voltage and current occur simultaneously, that is, in closed circuits (Burde & Wilhelm, 2020).

Lastly, Binnie (2001) suggests that the Electricity topic be taught by using its history, which recommends that classroom practical work should mirror the original experiments conducted by scientists to enhance the excitement of learner discovery. This is a good Australian strategy which might not be practicable in most rural South African schools, because they often lack laboratory facilities and resources. While on science discovery, Korganci et al. (2015) foreground the inquiry-based learning on electric circuit models for conceptual understanding, particularly the use of electric circuit mental models and a water circuit analogy as teaching aids which were found to be more effective when teaching Electricity than the traditional teaching method for Europe‘s high school learners.

2.5.2. Teaching and learning of the Electricity topic: Regional experiences

Regionally, Erinosho‘s (2013) findings revealed that teachers find it difficult to teach some physics topics, including the topic of Electricity, because they lack concrete examples and the topic requires mathematical manipulations or visualisation. Following this difficulty, Aboagye et al. (2018) recommended that teachers use the combination of inquiry-based, real, hands-on and computer simulation methods for the teaching of electric circuits. Aboagye et al.‘s (2018) recommendation might be reasonable and practical for schools with resources which include functioning science laboratories and technological resources, however, are often not readily available and accessible for most rural South African teachers.

Additionally, after categorising Ethiopian undergraduate students‘ alternative conceptions in Electricity (electric potential and energy), Dega et al. (2013) suggested a gradual, supportive approach to bring about students‘ conceptual change. Though the suggestions were made for university teacher-educators, high school teachers also need to consider the supportive approach for learners‘ conceptual change, especially when teaching about the ideas of electric potential and energy. Such a supportive approach should also consider the role of learner‘s prior knowledge, including misconceptions, for effective link-making on what learners already know and the conceptual understanding of the Electricity topic (Mbonyiryivuze et al., 2019). The importance of learner prior knowledge in the teaching of the Electricity topic has also been noted internationally that even at primary school level, learners‘ understanding of electric circuits is influenced by their prior knowledge (Preston, 2019); hence this study aimed to expose teacher considerations of learner prior knowledge when teaching the Electricity topic in high schools.

2.5.3. South African perspectives to the teaching and learning of Electricity topic

Locally, in the South African context, Boateng and Mushayikwa (2022) administered a Physical Science Achievement Test (PSAT) and Index of Learning Style Questionnaire (ILSQ) to South African physical science learners in their search for the learners learning styles and their determination of how much variance in Electricity and Magnetism academic performance can be explained by the variation in learning styles when they receive learning style-based instructions. Considering their findings, active, sequential, visual, and sensory were the predominant learning styles preferred by learners, even though is not clear if rural learners would prefer these same learning styles. The implications of the reported learning styles are not yet known concerning rural physical science teaching and learning. Though Electricity and Magnetism was the target theme for Boateng and Mushayikwa (2022), it only served as the context in their work, while their study focused on learners‘ learning styles, which is a different perspective to that taken in the current study.

Furthermore, Bradley et al. (2019) and Bradley and Moodie (2021) identified student-teachers‘ misconceptions about electric circuits and recommend a systemic approach to teaching and learning about electrical cells and circuits for deeper understanding. They suggest an approach that will consider the ideas of electrochemistry when teaching about Electricity in physics, a similar integration and concept-linking as that presented by Burde and Wilhelm (2020) in the context of electrostatics and electric circuit teaching. Lastly, South African teachers‘ ideas of teaching Electricity and their awareness of learners‘ misconceptions have been investigated. It was found that urban teachers view teaching factually, mathematically, practically, and conceptually as some of the teaching strategies that should be used to correct learner misconceptions (Moodley & Gaigher, 2015). How teachers actually teach this topic was silent in Moodley and Gaigher‘s (2015) research, addressing the importance of focusing on the rural teaching of the Electricity topic.

In relation to the 2015 work, Moodley and Gaigher (2019) have further explored South African science teachers‘ understanding of learners‘ misconceptions in relation to teachers‘ perceptions about teaching simple circuits. Their findings demonstrated that teacher understanding of learners‘ misconceptions do not always correlate with conceptual perceptions about teaching electric circuits. It is important to note that of the abovementioned research in South Africa, actual classroom teaching of the Electricity topic has not been the focus of research, hence the current study.

2.6. Difficulties with the teaching and learning of Electricity topic

Physical science is difficult to teach and learn because teachers and learners must contend with different representations such as experiments, formulas and calculations, graphs, and conceptual explanations and understanding to make transformations (Hlabane, 2016; Sebatana & Dudu, 2022). While this is the case, learners often demonstrate poor mathematical skills and lack of understanding the problem in the domain of problem solving skills in physics (Reddy & Panacharoensawad, 2017). Furthermore, within physics, topics such Electricity are perceived difficult to teach and learn because of the inconsistencies between the everyday and physics meanings attached to electricity-related concepts (Caleon et al., 2018; Maloney et al., 2001). Due to the complexity and abstractness of the Electricity topic and the misconceptions, learners have difficulty in conceptually understanding this section of physics (Bernardo, 2020).

The teaching pace of abstract and complex Electricity concepts makes it demanding for learners to internalise and make meaning of the concepts within a topic for deep understanding. The challenges with teaching pace could be justified in the South African Grade 10 physical science classrooms, because the topic is taught for about two weeks (one hour per day) just before the mid-year examination. This might put teachers and learners under pressure to complete the syllabus and understand the topic, while also rushing to revise the content that was covered in the first half of the year. The insufficient time to execute the required physical science curriculum components, because of overloading, results in teachers focusing on teaching for assessment (Mavuru & Ramnarain, 2017). This indicates limited time for teachers to cover the necessary physical sciences material, which in turn undermines conceptual understanding.

Moreover, the Electricity topic is one among many conceptually challenging topics because, unlike the Mechanics topic (with concepts relating to everyday experiences), the Electricity topic has sophisticated mathematical problems the teacher has to teach clearly and relationally for learners to understand and solve during the lessons to ensure epistemological access to the whole science knowledge. In essence, this topic contains difficult mathematical operations involving sophisticated problem-solving skills and learners find the concepts intangible and not directly able to be associated with daily life (Adeoye, 2010; Chasteen & Pollock, 2008; Guisasola, 2014). Additionally, Onder et al. (2017) produced two versions of a diagnostic instrument consisting of 29 questions to assess the conceptual comprehension of direct current resistive electrical circuits among college and high school students. The research found that after teaching about the electric circuits, most students continue to believe that a battery is a continuous current source in electric circuit connection. They further misunderstood fundamental terminology by ascribing the attributes of voltage to resistance and/or current, highlighting the difficulty of the Electricity topic.

Also, Tsakeni (2017) posits that learners arrive at school with preconceived notions which are incompatible with established scientific rules and theories because the notions are rooted in the culture, beliefs, language, and customs of the learners‘ local society. For example, Trengove (2012) argues that almost every Zulu, Xhosa, or Venda person, particularly in rural South Africa, knows that witches have the power to send lightning, kill livestock or burn houses, including the inhabitants. Conversely, learners are taught in science classes that lightning is generated by the accumulation of charges in the clouds. It is such ideas that teachers need to negotiate with learners for scientific conceptual understanding. Acknowledging the learners’ prior knowledge is important because is clear as individuals are not passive; rather, they interpret new knowledge considering their prior thoughts and experiences (Darling-Hammond et al., 2017). A science teacher is then tasked with the responsibility of devising effective conceptual strategies to navigate through learner prior knowledge to help develop conceptually sound scientific knowledge that is consistent with the values and principles of science. It is therefore important for teachers to be aware of the learners‘ prior knowledge, including difficulties and misconceptions, as they should inform their approaches during the Electricity lessons. Of concern is that, despite the scientific explanation underlying Electricity, teachers find it difficult to shift learners‘ previous misunderstandings (Noguera, 2018), as learners are often reluctant to change and this may impede the effective teaching and learning of the topic (Tsakeni, 2017).

The Department of Basic Education asserts that learners struggle with electricity-related concepts such as electric circuits, electrodynamics, and electrostatics (DBE, 2018). The department registers the following misunderstandings and problems as learning issues linked with the Electricity topic among South African learners which teachers need to address during the Electricity lesson: (i) use of incorrect equations to solve problems and poor mathematical manipulation; (ii) inability to state and apply Ohm‘s Law correctly; (iii) inability to simplify complex circuits; (iv) incorrect use and manipulation of the parallel resistors formula; (v) inability to interpret Faraday‘s law of electricity induction; (vi) inability to integrate concepts learned under Newton‘s law with electrostatics; and (vii) inability to differentiate between electromotive force and potential difference (DBE, 2018).

Moreover, there is the expectation that learners make measurements to determine, judge and calculate physical quantities they cannot directly observe (Li, 2012). Accordingly, one of the main challenges with learning Electricity is its sub-microscopic nature which at times is difficult for learners to comprehend. This was also established by Chabay and Sherwood (2006) who posit that, “In Electricity and Magnetism the student is quickly introduced to a world in which almost all the quantities are invisible; they are either microscopic such as electrons or abstractions such as field, flux, and potential" (p. 329). Of concern for the current study was the lack of knowledge and research to establish the nature of teaching, including challenges and difficulties, that rural teachers encounter during the teaching and learning of the Electricity topic.

As mentioned earlier, in rural schools, physical science is plagued with several problems such as insufficient infrastructural facilities, insufficient access to resources, underequipped laboratories, and undertrained teachers because the newly qualified teachers do not want to teach in rural schools (Mavuru & Ramnarain, 2017). Consequently, there is a shortage of both qualified and skilled physical science teachers. Moreover, research by Edu Source (DBE, 2017) indicates that most of the physical science and mathematics teachers are either underqualified or unqualified to teach these subjects, and some rural schools use teachers who are not trained to teach physical science, because the subject must be taught. Scholars refer to this teaching as out-of-field teaching as teachers must teach subjects in which they are not specialists (Pacana et al., 2019; Price, 2017). The Department of Education has revealed that even some qualified teachers lack competence in physical sciences instruction, and this has also been a concern at the junior secondary school level (DBE, 2017). In a context where teachers are tasked with the responsibility of using effective conceptual strategies to help learners build conceptually sound scientific knowledge consistent with the values and principles of science, it is concerning to have teachers with insufficient science knowledge. Darling-Hammond et al. (2017) maintain that learners in rural schools often lack access to well-resourced institutions and well-trained, experienced science teachers, which has been and continues to be a concern in a democratic South Africa for the past 29 years.

Furthermore, since "to study science is to learn a foreign language and unless one masters the language one cannot properly understand the science" (Childs, 2006, p. 17), rural learners are more disadvantaged because proficiency in the foreign language of science and comprehension of science subject matter knowledge is a challenge. Therefore, a physical science teacher must be cognisant of learners' challenges and should think of effective ways to empower learners towards being scientifically literate, to be able to think, speak and write about the Electricity topic ideas with confidence. While this is expected from the teachers, this study argues that little research has been done with Grade 10 rural teachers to understand the pedagogical approaches during the electricity topic lessons, and the pedagogical reasoning for the specific approaches.

2.7. Factors affecting the teaching of the Electricity topic in South Africa

Some of the challenges have already been mentioned in chapter 1, which have an impact on how the physical science topics, including the Electricity topic, are taught, and learnt. Some of these challenges included: lack of infrastructural facilities, insufficient access to resources, underequipped laboratories, undertrained teachers, and the distinction between the language of instruction and the language spoken at home, including in South African rural schools (John, 2019; Makgato & Mji, 2006; Ogegbo et al., 2019). Also, in the majority of South African classrooms, there is concern about the learners‘ low participation during the lessons, as they seldom ask questions and teachers often disregard learners‘ inaccurate responses rather than addressing them (Mika, 2018). Similarly, Molapo and Pillay (2018) identified some similar and different factors that influence physical science teaching, including the teaching of Electricity topic. These factors include, but not limited to, teachers‘ lack of subject matter knowledge and fundamental teaching skills, tension between African languages and culture (traditions), life outside the school setting, and the needed science culture of inquiry in the classroom, and teaching towards assessment rather than promoting learner engagement for meaning making.

2.8. Chapter summary

This chapter discussed the importance of understanding the nature of science, like exposing learners to various types of scientific models and scientific ways of thinking and doing, which could potentially shape the teaching of the Electricity topic. I argued that teachers should recognise that teaching and learning science involves conceptual change, and cultural border crossing and that representation of the concepts in the topic are of paramount importance to negotiate science meaning-making. Therefore, to teach the topic of Electricity, teachers should make the abstract concepts more accessible to learners through various teaching strategies, including use of effective representations and powerful analogies. The chapter has highlighted some of the key conceptual difficulties for teaching and learning about the topic of Electricity. Thus, understanding how the topic is taught was critical for this study. Further, what was more alarming from literature is that little is known about science teachers‘ approaches to Electricity teaching in rural contexts, regionally and locally. This means rural schools and rural teachers' voices have been overlooked by science education researchers, particularly in South Africa.

Moreover, the reviewed literature exposed the teaching and learning challenges associated with a rural context which might negatively influence the delivery of quality physical science education. The chapter reviewed the teaching and learning of physical science in South African rural schools, with a focus on the contextual difficulties that science teachers encounter when teaching the subject. Most studies on science teaching presume that urban and township findings can be generalised to the rural schools' context, a possible reason that little research has been done in South African rural contexts. The focus on township and urban schools overlooks the unique contextual factors that are embedded in rural contexts. It also undermines the vast knowledge that can be harnessed from the rural context in helping to improve physical science teaching and learning; and, in turn, performance in the subject in South Africa. Various authors posit that rural people and their knowledge, skills, and ways of doing things tend to be homogenised, disregarding various lived experiences of individuals within and across rural spaces. Hence the idea of moving beyond homogenising rural spaces and rural people (Balfour et al., 2008). Within rural areas, there are multifaceted factors that influence the teaching and learning of science, and these factors might shape the effectiveness of science teaching and learning.

CHAPTER 3

Reconceptualising teaching to support topic-specific knowledge building: Theoretical and Conceptual framework

3.1. Introduction

This study used Mavhunga's (2012) Topic-Specific Pedagogical Content Knowledge (tsPCK) theoretical framework and Scott et al.'s (2011) Pedagogical Link-Making (PLM) as the conceptual framework, as lenses to describe and understand the nature of teaching the Electricity topic in Grade 10 physical science rural classrooms. Mavhunga's (2012) tsPCK has been widely accepted and used in science education as a theoretical framework (Mavhunga & Rollnick, 2013; Mavhunga & van der Merwe, 2020), and in this study it is also used as a theory. I acknowledge that tsPCK is sometimes referred to as a model (Mavhunga, 2012; Roy & Bairagya, 2019), which depends on the researchers and focus of the research. To strengthen the theoretical framework, Scott et al.'s (2011) concept of PLM, particularly the pedagogical link-making to support knowledge building and pedagogical link-making to promote continuity, were appropriate for the study. This choice does not overlook the importance of the third form: pedagogical link-making to encourage emotional engagement, because teaching and learning involves emotions. However, for this study it is not appropriate because the study is pedagogical in nature and focus only on teachers and their pedagogical practices.

3.2. Pedagogical Content Knowledge (PCK)

TsPCK has its foundation in the work of Lee Shulman's proposal that pedagogy (a bridge) and the content should be treated equally, and conceptualised PCK for effective teaching of the subject matter knowledge (Shulman, 1986). PCK is the "special amalgam of content and pedagogy which includes … forms of representations of the ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1987, p. 9). This means PCK is an exceptional knowledge that a teacher needs to transform the subject matter knowledge into its teachable forms (Shulman, 1986), a reason it is uniquely the province of teachers for creating effective learning opportunities (Bishop & Denley, 2007;

Park & Chen, 2012). In science education, creative effective teaching is important because of abstract and challenging concepts that need careful organisation and representation for learners' meaning-making and understanding. It therefore means that teachers' knowledge of learners is essential and understanding learners' prior knowledge, possible conceptions and misconceptions, including the background factors that could hinder or enable effective and successful teaching and learning are important (Gunckel et al., 2018). This information addresses the importance of learners' prior knowledge and misconceptions about the Electricity topic, considering the used everyday language when electricity is talked about at home. In this study, learners' knowledge, which signifies a contextual background for teaching and learning, is therefore significant.

3.2.1. Reconceptualising PCK in Science Education

Largely grounded on the work of Shulman (1986), Geddis and Wood (1997) posit that a variety of knowledge types, including learner prior knowledge, representations, instructional strategies, curriculum materials, and curricular saliency, from which the subject matter transformation emerges, should be noted for the purpose of effective teaching. Shulman's concepts helped shape the science education research and science teaching by providing the knowledge base as the foundation for understanding what must be considered by teachers to enhance teaching and learning experiences. However, Ball and colleagues (Ball & Bass, 2000; Ball et al., 2008) from the mathematics education perspective, have argued that teaching requires a specialized form of pure subject matter, to ensure effective teaching and building of learners' knowledge. These arguments developed further and contextualised to science education. Figure 1 presents the PCK trends from Shulman to Mavhunga's tsPCK. The figure shows some aspects of PCK that have been carried through different conceptualisations of tsPCK. To exemplify this, consider the blue highlighted *knowledge of the learners* for Shulman; *students' prior knowledge* for Geddis and Wood; *conceptions and misconceptions* for Ball et al.; and back to s*tudents' prior knowledge* for Mavhunga.

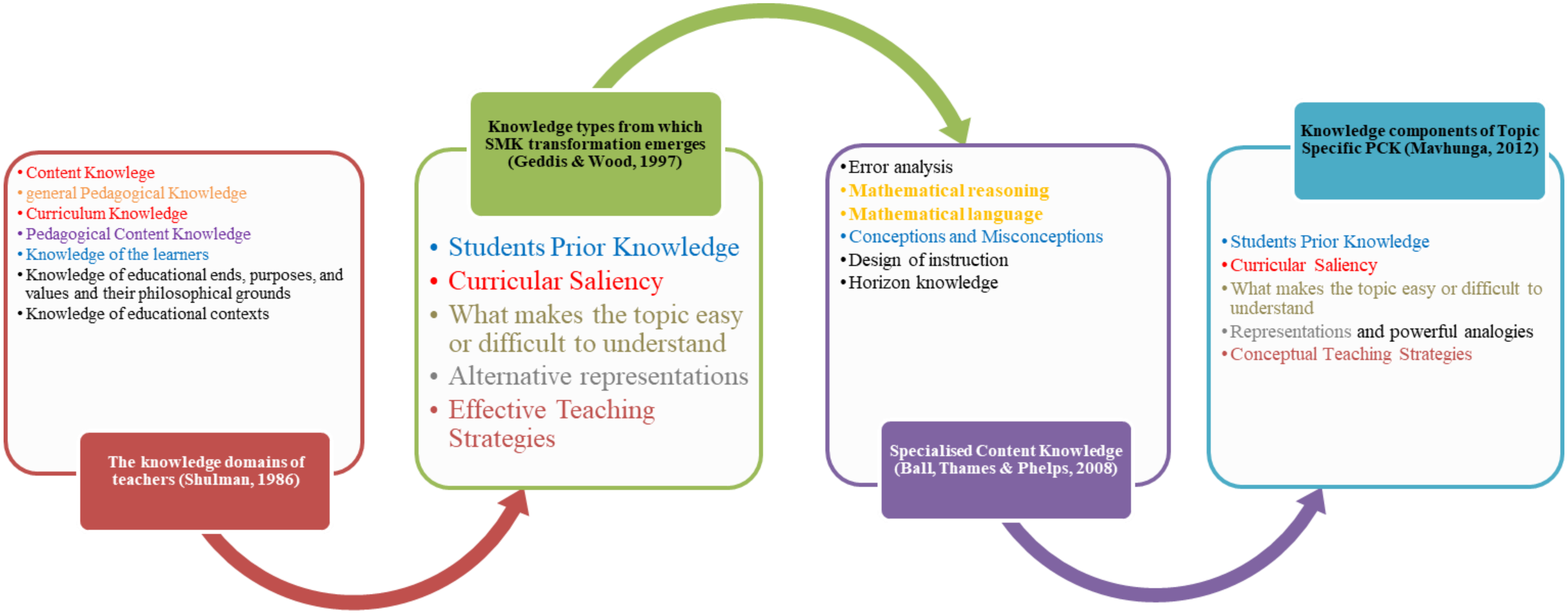
Taking the PCK discussion further, the science education researchers have also reviewed the relevance of PCK for their specific specialisation (Carlson & Daehler, 2019; Loughran et al., 2012; Magnusson et al., 1999; Mavhunga & Rollnick, 2015). In pursuit of contextualising PCK into the science discipline, in 2012, the science education researchers agreed on a PCK model for science education (Gess-Newsome, 2015) and this model was revised in 2017, leading to the Refined Consensus Model of PCK[13] (Carlson & Daehler, 2019). Figure 1 demonstrates the reconceptualisation of PCK from Shulman to the theoretical framework of this study— tsPCK. From Figure 1, I focus on topic-specific PCK and its five components. In light of the reconceptualised science-specific PCK, Connor and Shultz (2018) argue that a teacher‘s PCK can be examined at three different levels: (1) **discipline-specific** (a teacher‘s understanding of pedagogical concepts and strategies for teaching in a particular discipline); (2) **subject-specific** (a teacher‘s understanding of a particular subject within a discipline); and (3) **topic-specific** (PCK of a teacher will differ according to the particular topic being taught). Moreover, Carlson and Daehler (2019) have added another level to a science teacher‘s PCK, the **concept-specific** (knowledge of teaching a specific concept within a particular topic).

Without overlooking the importance of discipline-specific and subject-specific PCK, the topic-specific and concept-specific PCK are mostly important in this study because of the focus on Electricity topic and the concepts within the topic. Even though Mavhunga‘s (2012) tsPCK framework does not include the concept-specific PCK, it is included in this study as part of an important concept. Carlson and Daehler‘s (2019) and Connor and Shultz‘s (2018) argument for the science PCK framework is grounded on the idea that science as a discipline is taught differently from the teaching of arts, mathematics, or languages. Within sciences, the life sciences subject is taught differently from the teaching of chemistry or physics, while within chemistry or physics, different topics are taught differently, and the same applies to concepts within topics. This study focuses on the teaching of a topic-specific content (topic-specific PCK), and further pays attention to how teachers connect different concepts within the Electricity topic. This teaching cannot be generalised for the teaching of other topics in physical science because they are taught differently. Thus, Mavhunga (2012) and Mavhunga and Rollnick (2013) have discussed in detail what must be considered for the teaching of a particular topic in science education.

[13] I am aware that the latest model is RCM of PCK as opposed to tsPCK. However, tsPCK is the one that details the aspect of classroom teaching practices, hence its relevance and adoption for this study.

Figure 1

A summary of PCK knowledge that informed tsPCK



Note: SMK means subject matter knowledge

3.2.2. Topic-Specific Pedagogical Content Knowledge (tsPCK)

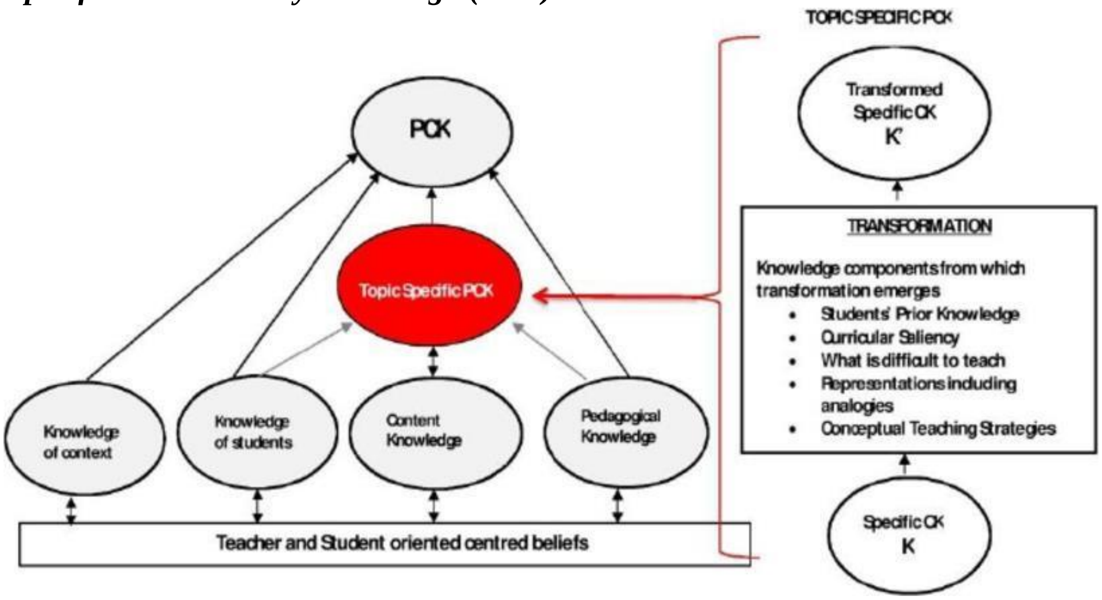
Following the science education debates at the time and with the aim of improving science teaching and learning experiences, Mavhunga (2012) and Mavhunga and Rollnick (2013) conceptualised topic-specific Pedagogical Content Knowledge[14] (tsPCK) to understand the important knowledge that a science teacher needs for teaching a science topic. The idea of tsPCK is premised on the notion that "PCK is construed as the blending of topic-specific content knowledge, pedagogical knowledge and knowledge of students' preconceptions and learning difficulties" (Mthethwa-Kunene et al., 2015, p. 1143). According to Mavhunga (2012), topic-specific PCK is a "construct referring to the capability needed to transform teachers' own comprehension of a given topic into formats that are suitable for teaching" (p. 20). This means that teachers must first comprehend the topic they intend to teach and think of effective teaching strategies for the development of deep scientific understanding. The tsPCK emphasises the importance of teachers' content knowledge to apply appropriate pedagogical strategies in order to teach a topic (Luft et al., 2011; Oh & Kim, 2013). Figure 2 represents the tsPCK components, in relation to Shulman's initial presentation of PCK.

The part of tsPCK on the right hand-side in Figure 2 emphasises the transformation of content knowledge through five components: (1) learners' prior knowledge including misconceptions (LPK); (2) curricular saliency (CSA); (3) what makes the topic easy or difficult to teach and learn (WDT); (4) representations including powerful examples and analogies (REP); and (5) conceptual teaching strategies (CTS) (Mavhunga, 2012). On the left-hand side, the figure shows the overall PCK model consisting of four generic knowledge domains, which teachers should draw from to make their PCK. Such knowledge domains are knowledge of context; knowledge of students; content knowledge; and pedagogical knowledge (Grossman, 1990; Davidowitz & Rollnick, 2011).

[14] Even though the Refined Consensus Model (RCM) of PCK clearly shows that even at collective PCK level and personal PCK, there is topic-specific PCK. It is not detailed how the tsPCK fits into those realms. However, on the enacted PCK realm, Carlson and Daehler (2019) state clearly that this is the knowledge utilised in a particular setting with a particular group of learners for them to learn a particular concept or collection of concepts – topic and it "is so specific to a particular science teaching episode" (Carlson & Daehler, 2019, p. 85).

Figure 2

Topic-specific PCK model by Mavhunga (2012)



Another important aspect for this study is the knowledge of context as a crucial aspect for teaching and learning (Choi & Hannafin, 1995) as also indicated in the PCK model, which is not prominent in the tsPCK model (on the right-hand side of Figure 2). This is important because in this study rural science teachers have considered rural contextual factors as crucial in their lesson planning and ultimately enactment of Electricity lessons, which concurs with the findings of Zulu (2018) on rural science education. This study notes that the quality of science teachers' tsPCK in the Electricity topic could be based on the understanding and the interactions of the five tsPCK components discussed below, to provide the suitable pedagogical practice for the Electricity topic. The components are not discussed in hierarchy or order of importance.

3.2.2.1. Learner Prior Knowledge (LPK)

The first component is the learners' prior knowledge, which includes their preconceptions and misconceptions of the topic being taught. Learner prior knowledge refers to the knowledge that learners acquire impulsively and experientially through everyday occurrences, knowledge held prior to lessons, either obtained from previous lessons[15] and/or from everyday experiences (Rusznyak & Walton, 2011). Vygotsky refers to this knowledge as spontaneous because it is based on perceptual attributes and embodies elementary aspects of experienced reality (Ferreira, 2014). Shulman (1986) also emphasises the importance of teacher‘s knowledge of "the conceptions and preconceptions that students of different ages and background bring with them to the learning of those most frequently taught topics and lessons" (p. 9). Thus, a teacher with PCK should demonstrate a level of awareness for learners‘ pre-requisite knowledge, difficulties as well as misconceptions during teaching (Aydin & Boz, 2013). Similarly, Urban-Woldron (2014) suggests that teachers should be aware of learners‘ understanding before and during the lesson, to have insights into what they know, to what they do not know, and the kinds of alternative conceptions held by their learners. While there are expectations from the framework, it is also important to acknowledge that teachers are working within a prescribed curriculum in South Africa, which appears to shape the nature of interactions and teaching approaches in classrooms.

It is further important for teachers to confront misconceptions and confirm correct conceptions of a particular topic, because they are an obstacle to meaningful science learning, and unless confronted, they would cause learning difficulties. Some of the misconceptions include statements such as in electrical circuits, current is consumed (Arnold & Millar, 1987; Lee & Law, 2001), battery is the source of constant current rather than a constant voltage source (Duit & von Rhoneck, 1997) and interchangeably using electricity terminology, for example, voltage for current and vice versa (Engelhard & Beichner, 2004). It is worth noting that the abovementioned misconceptions are occasionally observed in classroom practices because some teachers hold the same misconceptions (Kucukozer & Demirci, 2005). For example, in this study, one teacher misunderstood and misinterpreted the connection of a voltmeter in measuring the voltage of a battery during her demonstration lesson, and convinced learners that she was right. This example shows a probable teacher misconception and a possible place of the role of teachers‘ prior knowledge of teaching a topic, including an explanation of concepts within the topic.

[15] Learners‘ knowledge from previous lessons could either be misconceptions or correct conceptions about certain concepts, hence the importance of gaining insights into this knowledge so as to confront misconceptions or confirm accurate scientific understanding.

Moreover, Park and Oliver (2008) contend that "as teachers developed better understanding of students' misconceptions, their PCK became more sophisticated" (p. 275). This means that teachers' understanding of, as well as their teaching approaches in confronting learners' misconceptions during teaching, is associated with teachers developing PCK. In this study, all teachers engaged, either consciously or unconsciously, with learner prior knowledge at different stages of their lessons. The prominent teachers' approaches observed in this study in exposing learner prior knowledge were recapping from previous lessons and constant questioning about content covered within the lesson, which are both encouraged by Scott et al. (2011) for promotion of concept progression and continuity. The questioned content must be understood individually and how it fits into the whole topic in making a coherent scientific story which requires a good understanding of curricular issues as detailed in the curricular saliency component of tsPCK.

3.2.2.2. Curricular saliency (CSA)

Curricular saliency describes teachers' knowledge of the topics in the curriculum, and how to sequence them in ways that will make content easily accessible to learners. This includes having knowledge of other topics (previous or upcoming topics) in relation to the taught topic, and this knowledge is evident in action (Geddis & Wood, 1997). The knowledge about previous, current, and upcoming concepts, including their links, resonates with Scott et al.'s (2011) concept of pedagogical link-making for continuity, which is discussed in section 3.3. The explicit understanding and acknowledgement of the knowledge from the previous, current, and upcoming concepts within and across lessons or grades helps make links between concepts which promotes continuity of knowledge, as argued by Scott et al. (2011). Curricular saliency is based on (1) structuring the topic into its Big and subordinate Ideas, (2) reflecting on the pre-concepts that are needed and, finally, (3) the sequencing of the Big Ideas in teaching the topic (Mavhunga, 2012). Furthermore, CSA embraces teachers' knowledge of core and peripheral concepts that enhances the transformation of specific content (Rollnick & Mavhunga, 2014). According to Loughran et al. (2012), "expert science teachers use this knowledge and information to shape the way they teach particular concepts" (p. 13). This means that teachers need to consider the curricular saliency aspect from the lesson planning stage to the execution of the lessons, which should help in planning out their time to be spent on each concept of a topic.

Moreover, Penuel et al. (2011) posit that teachers‵ knowledge of curriculum plays a significant role in improving outcomes of science teaching and learning. Curricular knowledge includes Electricity Big Ideas in this study, which were centred on the concepts of 'charges‵, 'potential‵, 'electric current‵ and 'electric circuits‵, and it was important for teachers to explicitly and coherently explain these ideas during teaching. From the classroom observations, all teachers followed the teaching plan as highlighted in the South African Grade 10 physical science curriculum and examination guidelines (see Appendix 14), which prescribes the teaching of magnetism, electrostatics, and then electric circuits, in that order (DBE, 2011). However, teachers spent more time on electric circuits than other concepts, and this could be due to the numerous calculations associated with this section. Moreover, the progression within the taught concepts was, to some extent, understood and linked with other concepts, even though links to other topics in the physics curriculum were not often explicit. The concept progression and relatively more time spent on electric circuits could be based on the difficulty and importance of electric circuits within the Electricity topic (Coetzee, 2021; Fino, 2018).

3.2.2.3. What is difficult to teach or learn (WDT)

During the lesson planning process, it is important for teachers to identify specific concepts that might be difficult for learners to understand, to ensure explicit detailed explanation of concepts. It is also important for the teachers to be conscious of the parts of topic that might be difficult to teach and explain effectively, to prevent learners‵ confusion and misunderstanding while promoting deep understanding of science concepts (Lodge et al., 2018). This addresses the importance of lesson planning, where a teacher think of different strategies to explain and clarify a challenging concept or part of the topic. Zhou et al. (2016) posit that "the ability to predict students‵ ideas or performances is commonly seen as an indicator to measure teachers‵ knowledge of students‵ difficulties and misconceptions" (p. 376). To illustrate this, when learning Electricity-related concepts, Kucukozer and Kocakulah (2007) indicate that learners have difficulty with understanding the idea of '*switching on and off*‵‵ the switch in a circuit and its effect on other components in an electric circuit. Such a difficulty is triggered by everyday talk where "in everyday language, expression such as 'close the switch' to light off a lit bulb and 'open up the switch' to lit the bulb are used" (Kucukozer & Kocakulah, 2007, p. 107). It is such difficulties that teachers need to be aware of before and during the teaching of electricity-related concepts, to correct the use of language and meaning for physical science learners. Thus, identifying challenging concepts requires teachers to have knowledge of gate-keeping concepts in a specific topic, and which concepts might be difficult to either teach or to learn.

Additionally, during classroom observation, one participant teacher had difficulty explaining the same concept of 'switching on and off' the switch while demonstrating using the classroom switch on the wall. Even though the teacher might have taken the explanation of the concept for granted during the lesson planning, the explanation challenge addresses the importance of continuous practise before the lessons. Thus, having knowledge about what is difficult to teach in a topic or what might be difficult for learners to comprehend in the subject matter is crucial when teaching science, especially the Electricity topic that uses lot of everyday practices which could be difficult for learners (Depaepe et al., 2013). Lastly, when investigating the teaching of chemical reactions, Usak et al. (2011) report that most chemistry teachers did not show evidence of being conscious of the conceptual difficulties their learners might face when learning the topic. This study then exposes physics teachers' considerations, or lack thereof, for what is difficult to teach or learn in the Electricity topic. Of importance for this study, were the multiple electricity-based representations that teachers used to flash out abstractions while enabling epistemological access to concepts that may be viewed as difficult to teach or learn.

3.2.2.4. Representations (REP)

Representations are necessary to visualise the concepts that are taught in class, and these refer to the best forms of representing a concept at symbolic, macroscopic, and sub-microscopic level, including moving from one level to the next when teaching a concept/s (Permatasari et al., 2022). It is important to visually represent the content of the subject, to support knowledge building (Scott et al., 2011) while enhancing learners' understanding of the topic and the related concepts that build the topic. In doing this, teachers need to demonstrate the experience of using different levels of representations in explaining different concepts of a topic, as concepts are articulated across different media of representations when used (Cheng & Gilbert, 2009; Scott et al., 2011).

As part of representing concepts, teachers and learners use illustrations, demonstrations (models), mathematical equations, graphical, diagrammatic, pictorial, and other modalities of representation to represent and formulate the subject in forms that make it comprehensible (Carrejo & Marshall, 2007; Shulman, 1986). By using different modes of representations, teachers can stimulate learning interest by supporting and encouraging learners' constructive and critical thinking about the topic (Prain & Tytler, 2012).

While it is important to use representations, they must be well executed and understood correctly within their context of use, because incorrect practice might lead to learners' misunderstanding of the intended concepts or they might misunderstand the representation. To exemplify this, one teacher incorrectly connected wires to a voltmeter when practically measuring an emf of a 6 Volts battery. The voltmeter overshot and the connecting wires overheated, and the teacher convinced learners that the measured emf of a 6 Volts battery was 3 Volts. The above scenario highlights the importance of teachers' knowledge of and effective use of any form of representation to aid teaching and learning of the Electricity topic and concepts. Moreover, the use of pictures, models, charts, and analogies has been found to be effective in making learners understand abstract aspects of electricity, like flow of charges at macroscopic and sub-microscopic levels (Korganci et al., 2015; Métioui & Trudel, 2012). In this study, teachers predominantly used mathematical equations (signs and symbols), analogies, demonstrations, and diagrammatic representations during the Electricity topic lessons. Even though pictures and charts could be considered one of the easiest representations for teachers, I did not see any usage in the three classrooms I observed, which addresses some of the challenges in the rural schools that cannot be taken for granted. This will be discussed in detail in Chapters 6 to 9.

3.2.2.5. Conceptual teaching strategies (CTS)

Conceptual teaching strategies refer to teachers' pedagogical approaches that enhance the teaching of concepts within a particular topic in a subject. Important to note about conceptual teaching strategies is that it draws from the other four tsPCK knowledge components (Mavhunga, 2012). Teachers need to choose strategies that: (i) meet the overall objectives of the lesson, (ii) consider confirmation or confrontation of learner prior knowledge and/or common misconceptions, (iii) consider aspects related to curricular saliency (which is sequencing, what not to discuss yet, emphasis of important conceptual aspects, etc), (iv) use either the macroscopic or symbolic representation with sub-microscopic representation to enforce a singular aspect of a concept, (v) and the strategy where a conceptual approach is clear (Connor & Shultz, 2018; Geddis & Wood, 1997; Stender et al., 2017).

Moreover, CTS refers to the effective and thoughtful teaching strategies to address the dynamics of teaching a specific topic. Also, CTS acknowledges teachers' awareness of possible confusion and misconceptions that could be caused by the content knowledge of the topic to learners. With the abovementioned, CTS recognises that using teaching techniques or general pedagogical approaches alone cannot guarantee learning, because these approaches are not specific to concepts (Loughran et al., 2012), hence a focused conceptual teaching strategy proposed by the tsPCK framework. Notwithstanding its role in teaching and this study, CTS in its current form is broad and does not give meaningful insights into all the teacher activities in classroom; hence a need to strengthen this aspect of the framework. The tsPCK's conceptual teaching strategies offer part of the '*what'* teachers have to do or consider, but it has not been explicitly detailed in the literature. To strengthen the understanding of the 'what' teachers have to do, I draw from Scott et al.'s (2011) form of pedagogical link-making to engage with 'how' the Electricity topic and related concepts were taught.

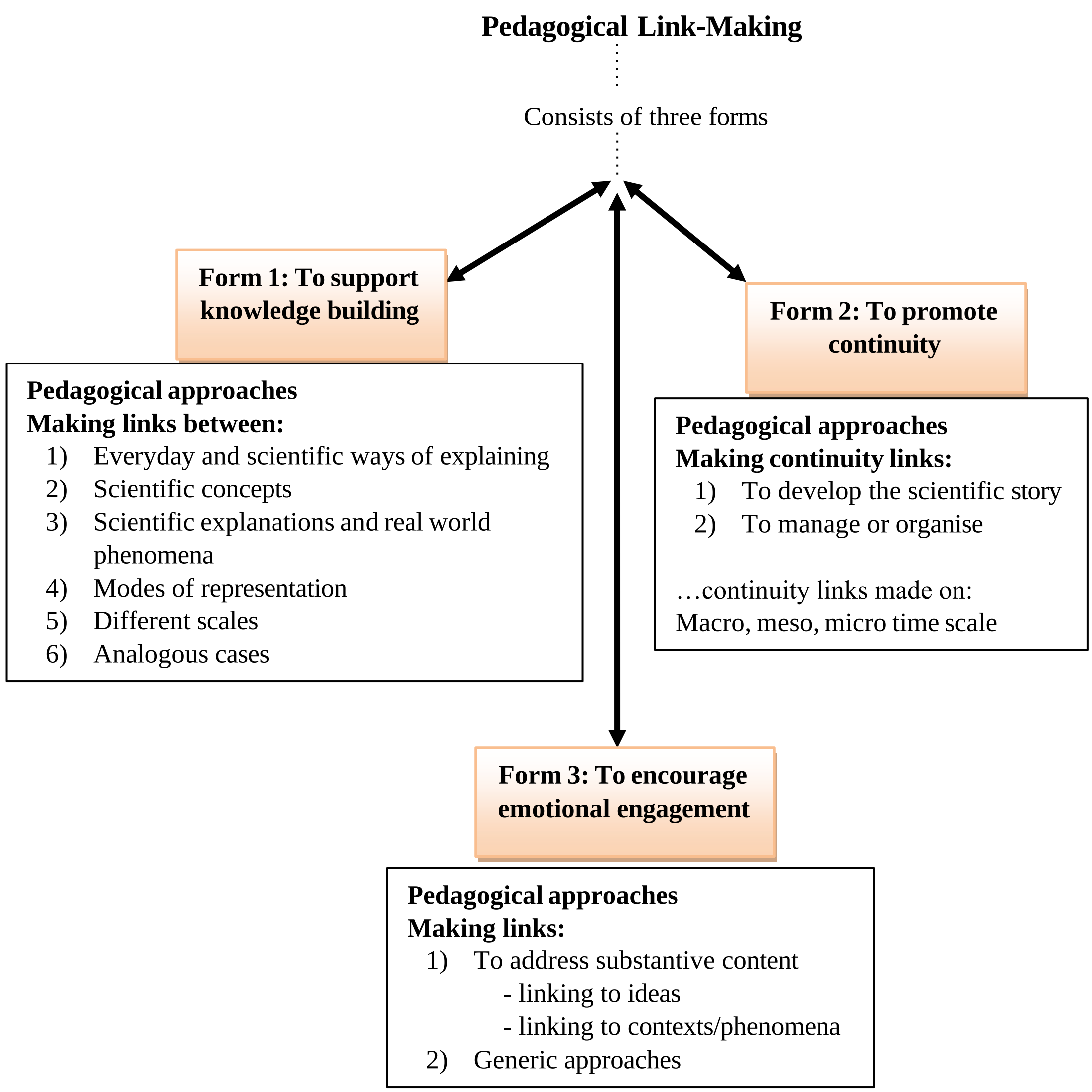
3.3. Pedagogical Link-Making

As already mentioned above, Scott et al.'s (2011) concept of PLM was instrumental in supporting the tsPCK framework. Finding its inspiration from the work of Vygotsky's socio-cultural perspective, PLM refers to ways in which teachers and learners make explicit connections between ideas in the ongoing meaning-making interactions of classroom teaching and learning (Scott et al., 2011). Similarly, Lehesvuori and Ametller (2021) describe PLM as referring to both the process of meaning-making and the knowledge being constructed. Construction of scientific knowledge is at the core of PLM and sees learning scientific conceptual knowledge as entailing a passage from social to personal planes through a process of internalisation (Scott et al., 2011). In this process, learning would involve making links between existing knowledge structures and new ideas (Staarman & Ametller, 2019). Consequently, science teaching should involve making links between learner prior knowledge, including their misconceptions, and the new knowledge taught. It further links between previously taught concepts and new target concepts, between knowledge structures of other topics in the science curriculum and knowledge of the Electricity topic, among other links. These links resonate with learner prior knowledge and curricular saliency of tsPCK as discussed in section 3.2 and help learners to construct their scientific understanding (Karlsson et al., 2020).

Moreover, pedagogical “links can be presented as an explicit way of showing the internal structure of the knowledge to be constructed, they can be offered as a way to reinforce the knowledge being constructed, or as a means to scaffold the construction” (Lehesvuori & Ametller, 2021, p. 4). The quality of links made during teaching plays an important role in how learners construct scientific knowledge for themselves. Scott et al. (2011) posit that “if link-making is not addressed through teaching, then it is unlikely to emerge in students‘ learning” (p. 5). It is thus important to make explicit links to support electricity knowledge building and to promote intellectual continuity and progression of concepts within the Electricity topic and across science topics. Furthermore, PLM as a conceptual framework, was used as a lens to understand and to analyse the way teachers engaged with the Electricity topic and concepts relationally, if at all, to understand the nuances of teaching the Electricity topic in Grade 10 rural classrooms. There are three forms of pedagogical link-making: 1) to support knowledge building; 2) to promote continuity; and 3) to encourage emotional engagement. Figure 3 demonstrates the three forms and associated approaches. The first two forms are used with all their respective approaches because of their relevance to the focus of this study.

Figure 3

Forms and approaches to pedagogical link-making (adopted from Scott et al., 2011)



3.3.1. Pedagogical link-making to support knowledge building

This form requires teachers to make connections between different kinds of knowledge to support learners in developing a deep understanding of the Electricity topic and its concepts. Under this form, I utilised all six pedagogical link-making approaches a teacher could use to support electricity knowledge-building and ensure that learners build their understanding of the relationship within concepts and between concepts that make a topic.

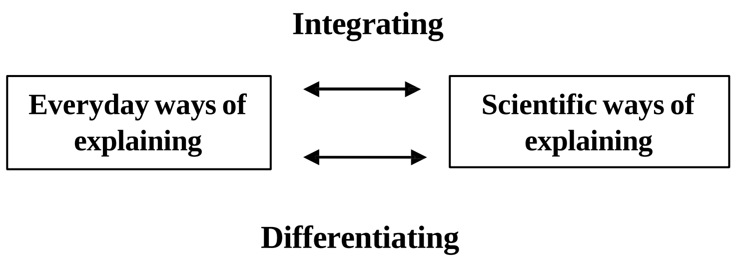
3.3.1.1. Approach 1: Making links between everyday and scientific ways of explaining

Science teaching and learning inevitably occur against a backdrop of everyday/spontaneous ways of talking and thinking about phenomena (Bakhtin, 1981; Scott et al., 2011). The teacher‘s role in this approach is to differentiate the everyday explaining of science phenomena with the science way of explaining. Vygotsky (1986) drew attention to the distinction between scientific and spontaneous (or everyday) concepts, and scientific concepts are the products of specific scientific communities and constitute part of the disciplinary knowledge of that community. For example, the concept of dissolution, which, in its everyday explanation for the learner is that dissolution of a substance like salt means changing from solid form to a liquid form, or after dissolution, a new substance is formed, or during dissolution, a solute is absorbed by the solvent (Uzuntiryaki & Geban, 2005). Whereas the scientific explanation is that all ionic solutes like salts are compounds made up of positive and negative ions. The process of dissolving a salt in water, involves three main steps: breaking the ionic bonds of the salt, breaking the hydrogen bonds in the water, and bonding water molecules to the ions (hydration). In the process, the solute breaks down into smaller invisible particles that are surrounded by particles of the solvent (Uzuntiryaki & Geban, 2005).

According to Scott et al. (2011), sometimes overlapping (or similarity) occurs between the everyday and scientific ways of explaining, whilst in other areas the two ways of explaining might be quite different. Where there is overlap, learning involves making links to *integrate* the scientific way of explaining with everyday views and where there is a difference in ways of explaining, learning involves making links to *differentiate* the scientific way of explaining from everyday views. These links are to be explicitly made by teachers and then appropriated by learners. This is important for teachers to be aware of, because the concepts of the Electricity topic, for example, current, resistance, potential, and energy, largely follows everyday or common sense views and learning therefore involves integrating and at times differentiating the formalised scientific view with existing ideas for deep understanding of scientific concepts (Scott et al., 2011). Figure 4 demonstrates these important links to be made by teachers when teaching science.

Figure 4

Integrating and differentiating everyday and scientific views



3.3.1.2. Approach 2: Making links between scientific concepts

Scott et al. (2011) argue that learning scientific conceptual knowledge also involves recognising how the scientific concepts fit together in an interlinking system, because there is no science concept that can be considered as an individual unit. This recognition is important because the usefulness of concepts comes from their connections to one another for a concept system to be developed. For example, in the Grade 10 Electricity topic, a deep understanding would be achieved if the teacher and learners engage with the relationships between various concepts, including charges, charge conservation, potential difference, voltage, emf, current, resistors (parallel and series resistors). In this way, a learner would be able to draw upon conceptual networks of interrelated concepts to account for the electricity phenomenon.

Lehesvuori and Ametller (2021) maintain that concept connection to facts and links between scientific concepts, including the extent scientific concepts are linked to create the scientific storyline during teaching, often leads to deep understanding of scientific concepts and processes. This approach supports the ideas of curricular saliency in that the teacher needs to acknowledge connectedness of concepts within the Electricity topic and across topics in the science curriculum. In this study, all teachers often connected concepts during teaching by drawing from previous grades' concepts and also mentioning some concepts during teaching and explicitly stating that these concepts will be covered in detail in the subsequent grades.

3.3.1.3. Approach 3: Making links between scientific explanations and real-world phenomena

There is a relationship between this approach and the first approach because of the intention to show the link between spontaneous and scientific concepts. Vygotsky caution that the challenge will be for the teacher to saturate scientific ideas with the concrete, for learners to see the connections between scientific constructs and the real world (Vygotsky, 1986). The teacher plays a crucial role in making the links between scientific explanations and real-world phenomena, by creating connections between what learners are learning with their previously acquired knowledge and with their life experiences outside the classroom. In chemistry component of physical science, Gabel (1993) argued that if the chemistry concepts are taught out of context of everyday life, "students compartmentalized the knowledge as that learned in school, versus that needed in everyday life" (p. 193). This implies that the science teacher's talk should be as relevant to the real world situations of the learner as possible, for easy connection and understanding. Johnstone (1991) posits that although the context is important for the conceptual understanding of science, it is imperative that the context is familiar and simple for learners.

In creating the links, the teacher can make choices in selecting the phenomena and these choices could be influenced by the potential interest and relevance of the phenomena to learners; or its potential to act as a memorable event (Scott et al., 2011). For example, in this study, some teachers related the idea of house wiring (connection) to parallel resistor connection to bring a practical foundation to the scientific explanation. Such relations are important when teaching about the Electricity topic because of its nature, a reason it is crucial for teachers to be careful when they teach the topic and its concepts. This approach is important so that learners' developing system of scientific concepts does not become an edifice of scientific explanation and generalisation without practical foundation (Scott et al., 2011). Therefore, a science teacher must saturate scientific ideas with the concrete so that learners can see connections between electricity constructs and the real world.

3.3.1.4. Approach 4: Making links between modes of representation

This approach links with the representation component of the tsPCK framework and this approach strengthens the tsPCK framework by focussing on linking the different modes of representations. For Lemke (1998), developing a deep understanding of scientific concepts must entail the ability to make links between different modalities of representation. While the technical verbal language is important in the teaching and learning of physical science, including the Electricity topic, the electric circuit symbols, mathematical representation (Electricity topic equations), graphical, diagrammatic, pictorial, and a host of other modalities of representation are crucial to support deep understanding of scientific concepts. All the multimodal representations have scientific meanings when used in the Electricity topic to promote deep understanding of electricity-related concepts, and the teacher should carefully use multiple representations and make links between them to prevent confusion. Scott et al. (2011) highlight the teacher‘s role to support learner‘s learning of how to integrate the various representations of scientific concepts, which involve moving between different modes of representation to support the link-making processes of their learners.

In all the observed lessons in this study, teachers used mathematical and diagrammatic representations, including electric circuit symbols. They used the representations to demonstrate the concepts of power, voltage, current, resistance symbolically; and these concepts and resistors were then represented through diagrammatic representations (electric circuits) to promote deep understanding of current and voltage in relation to resistors (resistance). Even though Scott et al. (2011) posit that teachers often find it challenging to support learners in learning how to integrate the various representations of scientific concepts, it was interesting to observe in this study how some teachers moved between symbolic representations of current, voltage, resistance; and the analogies; and diagrammatic representations of electric circuits to paint a full picture of current flow in respect to supplied voltage and resistance.

3.3.1.5. Approach 5: Moving between different scales and levels of explanation

Again, this approach links and strengthens the component of representations from the tsPCK framework by focussing on how to move between different scales of explanations. In this approach, the teacher must navigate between the *macroscopic* (phenomenological), *sub-microscopic* (theoretical) and *symbolic* levels of explanations. It is noted that learners generally memorise and regurgitate equations without comprehension of the changes that occur at microscopic level. Scott et al. (2011) argue that science, including the Electricity topic, is essentially symbolic and learners need to learn the social language of science with all its specificity, such as electric circuit symbols, formulae, diagrammatic representations, and mathematical equations involved in the Electricity topic. This symbolic nature of the Electricity topic needs to be linked with the macroscopic nature of the topic. The macroscopic level of explanations relate mostly to the concrete and visible phenomena, like the glow of a light bulb in a complete electric circuit.

Moreover, both the symbolic and macroscopic nature of the Electricity topic must be linked to the micro or sub-microscopic level, which includes the flow of current in the Electricity topic. The teacher needs to make explicit links from symbolic, to macroscopic and to sub-microscopic levels of explanations. However, Chandrasegaran et al. (2008) note that the difficulty of the symbolic and submicroscopic levels is since they are abstract and cannot be experienced as they are not visible or tangible, which means teachers need to be careful when they use them. For example, in this study, one teacher taught about the flow of current and the idea of voltage, and represented these symbolically and brought the instruments to demonstrate so that learners could measure voltage and current, while also connecting an electric circuit characterised by the glow of connected light bulbs for learners to experience the abstraction associated with current and voltage.

3.3.1.6. Approach 6: Analogical link-making

The final approach is helpful in supporting learning and it involves a teacher helping learners towards an understanding of a scientific target concept, or way of explaining, by making an analogy to a more accessible or familiar case (Scott et al., 2011). Thus, the internal resistance in an electric circuit might be likened to having 25 litres of water poured into a lengthy pipe and collecting the same water but less in amount (< 25 litres) at the other end of the pipe, as used by one of the teachers in this study to make the scientific concepts available to learners. Though important, teachers need to be careful when and how they use analogies, because they could confuse learners if are not used appropriately. One of the cautions to be considered by teachers is making known the shortcomings of an analogy as it may propagate the development of alternative concepts (Dagher, 1995). As argued further by Dagher (1995), analogies may bring conceptualisation of knowledge in learners but, if not well chosen and when its shortcomings are not explained to learners, it may mislead learners. Considering this view, all the rural physical science teachers in this study, did not make clear the intentions and shortcomings of their chosen analogies even though concepts demonstrated through the used analogies were explicitly referred to.

3.3.2. Pedagogical link-making to promote continuity

This form requires teachers to make conceptual knowledge links within lessons and across lessons, including across school grades. This could be done, for example, through recapping the previous lesson‘s content and building on this knowledge for the present lesson. Two pedagogical link-making approaches have been identified as being fundamentally important in establishing the cumulative nature of teaching and learning and counteracting the tendency for learners to experience schooling as a series of isolated, disconnected events (Scott et al., 2011). These approaches are: 1) to develop the scientific story, and 2) to manage or organise. Of importance, each approach has an associated time scale ranging from micro, meso, and macro scale. The micro scale focuses on continuity links on a short time scale (typically of minutes) within a lesson; and the meso scale centres on continuity links made on an intermediate time scale (typically of days/weeks) across lessons; while the macro scale is concerned with continuity links made on an extended time scale (typically of months/years), usually across school grades (Scott et al., 2011).

3.3.2.1. Approach 1: To develop the scientific story

The approach is concerned with the development of conceptual knowledge from one segment of the lesson to the next, from one lesson to the next, and from one school grade to the next. Part of the techniques to ensure this development include *recapping*, where the teacher reviews events from earlier lessons in setting the scene for the current activity; and *elicitations*, which usually take the form of questions that seek to obtain from learners information gained in the past classroom activity which is relevant to current or future activity (Scott et al., 2011). The above techniques can be used on the macro scale, the meso scale and at the micro scale. Teachers can also connect previous grades information with the current lesson, to show learners concepts continuations and relationships between the topics, which was observed during the lessons in the current study. Two teachers explicitly and continuously used macro time scale to remind learners what they did in previous grades about the topic, even though at some point they also made assumptions that learners did the topic(s) and that learners were conversant with previous grades knowledge.

The pedagogical approach to promote continuity has associated time scale with three levels, and teachers need to coherently use them during the lessons support learners‘ systematic and higher order thinking about science concepts. Tiberghien et al. (2007) explain the three-time scale levels:

a) Macro: continuity links made on an extended time scale (typically of months/ years), which involve making references to teaching/learning in different parts of the science curriculum.
b) Meso: continuity links made on an intermediate time scale (typically of days/ weeks), which involve making references to different points within a lesson sequence.
c) Micro: continuity links made on a short time scale (typically of minutes), which involve making references to different points within a lesson.

The importance of scientific story during teaching is presented by Schlotterbeck et al. (2020) that the connection and links between scientific concepts and the extent scientific concepts are linked to create the scientific storyline has an impact on student learning. Thus, conceptual networks and maps have been constructed to present the extent to which different concepts are linked together and models of conceptual networks have been portrayed to grasp the holistic picture of the scientific contents of the classroom discussions (Caballero et al., 2017; Schlotterbeck et al., 2020). Communicative approach is crucial in supporting scientific story during the lessons, because it depend on the nature of discourse and teacher‘s and learner‘s interaction, hence teacher‘s approach to the topic.

3.3.2.2. Approach 2: To manage or organise

A continuity link to manage or organise knowledge does not add new elements to the scientific story development but is commonly used during transitions from one activity to another and therefore tends to relate to a micro time scale (Scott et al., 2011). This was observed in some parts of the lessons, where the teacher would stop learners from a task to move on to another task or when the teachers were ending their lessons. This approach is also important for continuity purposes. Having discussed tsPCK‘s and PLM‘s relevant forms and approaches, it is equally important to bring the two frameworks (tsPCK and PLM) together to demonstrate how they complemented each other while offering an insightful perspective into the analysis and meaning-making of the findings for this study. The following section discusses the tsPCK–PLM relationship and this discussion is further strengthened in Chapter 5.

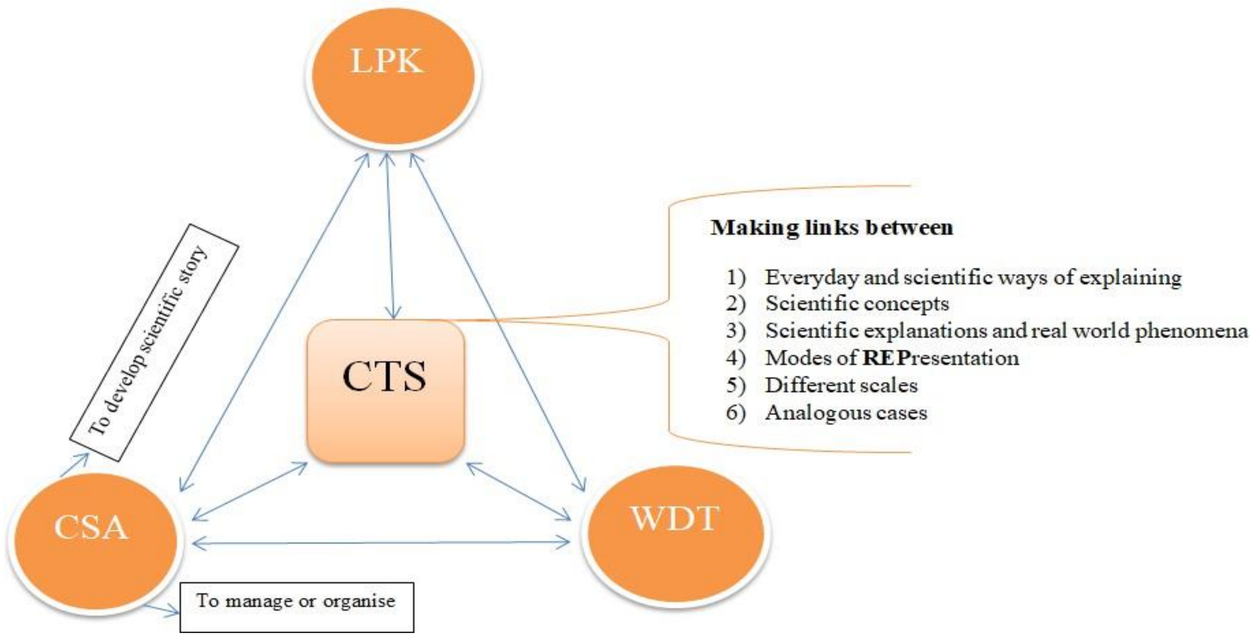
3.4. Teachers' tsPCK to support knowledge building

Though topic-specific PCK and PLM were presented separately in the previous sections 3.2 and 3.3 respectively, the discussions in these sections were integrative in how they informed the current study. In this section I present the connection between the two frameworks to show how they assist each where there are gaps in one framework, to inform each other and frame this study. The tsPCK framework was not explicit in the actual classroom interactions between the teacher and learners; teacher and content; and learners and content for the development of a scientific story. The explicit description of classroom interaction is important for this study as I observed all teachers interacting with learners differently during the Electricity topic lessons. For example, during the classroom observation, teachers built scientific stories differently across lessons and from within lessons where demonstrations, classwork, or assessment corrections, among others, were used by teachers. Therefore, PLM facilitated the understanding of effective teaching for meaning-making and also shed light on how science teaching is to be approached to enable epistemological access to the Electricity content.

Furthermore, the classroom observation data of this study has exposed a need to supplement the tsPCK framework, especially the component of CTS, if teachers‘ topic-specific PCK is to be captured holistically in action. Therefore, to supplement CTS, I utilised Scott et al.‘s (2011) concept of pedagogical link-making with the focus on link-making for knowledge building, while link-making to promote continuity also advanced other practical aspects of curricular saliency components of tsPCK. Holistically, tsPCK and PLM provided a suitable lens to understand teacher knowledge needed for the teaching of the Electricity topic and how to analyse this knowledge from observed teacher action. Thus, I have termed this lens, "*Teachers‘ tsPCK to* *support knowledge building*". Figure 5, visually illustrates the relationship between tsPCK components and PLM's forms of link-making for knowledge building and link-making to promote continuity.

Figure 5

Teachers' tsPCK to support knowledge building



From Figure 5 above, LPK, CTS, CSA, and WDT are the components of tsPCK as discussed in section 3.2. The last component, REP, links directly with pedagogical approaches 4, 5, and 6 of PLM in Figure 5 and is indicated by REP in approach 4 in the figure. Figure 5 has strategically located CTS at the centre of an observable teaching while it draws from all the other tsPCK components, including the two PLM's forms. To exemplify the representation's usefulness, some teachers in this study were observed making links at meso and micro scale to ascertain learner prior knowledge of a concept they deemed difficult to teach or learn and then used different modes of representations to explain such concept(s). The double arrows (⟷) in Figure 5 between CSA-CTS-WDT-LPK shows a two way knowledge exchange, which is direct or visible during the classroom teaching. There is no order in how these components appear during teaching. The single arrows (⟶) between CSA and link to manage or organise; CSA and link to develop a scientific story, represents the subsets of CSA which shows only a direct or visible knowledge exchange. This is because, in this study, CSA manifested more often through the link to develop a scientific story and occasionally through the link to manage or organise.

3.5. Chapter summary

This chapter has discussed the complementary nature of tsPCK and PLM as working frameworks that were used to conceptualise, analyse, and make sense of the findings for this study. Mavhunga's (2012) tsPCK has provided the important knowledge that physical science teachers need for teaching the Electricity topic. In this aspect of the framework, the importance of teachers' content knowledge has been emphasised for teachers to be able to apply appropriate pedagogical strategies in teaching a science topic. Some of these topic- and concept-specific pedagogical strategies have been provided by Scott et al., (2011) through PLM. This is where teachers should use their content knowledge of the topic to build scientific knowledge by constantly making important pedagogical links. The next chapter focuses on the research processes followed to address the aims and questions of this study.

CHAPTER 4

Researching with Rural Schools: A Research Methodology

4.1. Introduction

Research is viewed by Shah and Al-Bargi (2013) as a systematic and methodical process that investigates a phenomenon, addresses a specific issue, answers a particular question to solve specific problems, and contributes to the existing knowledge in a particular field. Resonating with this view, Creswell (2012) outlines research as a procedural way of problematising an issue and collecting and analysing information to broaden our understanding of the problematised phenomenon. This helps to deconstruct and reconstruct the prevailing theorisations of the subject under scrutiny based on newly discovered information. In light of Creswell‘s (2012) notion of research, this study has explored teachers‘ pedagogical practices and adds new knowledge into science education research in this field. Therefore, in this chapter, I present the research paradigm, design, approach, methods of data generation, and data analysis tools that were chosen to address the problematised issue in section 1.3. Additionally, ethical considerations and techniques to address issues of trustworthiness of the findings are also presented at the end of the chapter. I begin the chapter by discussing the research paradigm which informed the conceptualisation of this study.

4.2. Research paradigm

This study uses the critical interpretivism paradigm to explore teachers‘ pedagogical approaches during the Grade 10 Electricity topic lessons. A research paradigm is a basic worldview that guides the researcher to observe and understand a particular phenomenon (Babbie, 2011; Shah & Al-Bargi, 2013). According to Kuhn (1970), a paradigm refers to “the entire constellation of beliefs, values, techniques shared by members of a given scientific community” (p. 75), which means a paradigm is a frame of reference to understand the phenomena. Before I discuss the critical interpretivism paradigm, I briefly present the nature and philosophical positions of other paradigms and the reasons they were not chosen for the study.

According to Aliyu et al. (2015), Kivunja and Kuyini (2017), and Rehman and Alharthi (2016), positivist, critical, and interpretivist paradigms are three principal paradigms because of their underlying philosophical assumptions of the world. Positivism subjects human behaviour to rules and views it as something experimental, hence positivism was not relevant for this study because it defines life in measurable terms rather than inner experience, and excludes notions of choice, freedom, individuality and moral responsibility (Cohen et al., 2011). With its origin from the Frankfurt School of Social Research, critical paradigm challenges oppression and beliefs that restrict human freedom and thus seeks to bring about social change and freedom (Okesina, 2020). Status quo is critiqued by this paradigm. Locating its ontology in historical realism, critical paradigm focuses on understanding the live experiences of people in their context (Guba & Lincoln, 1994; Okesina, 2020). The critical paradigm situates its research in social justice issues (Kivunja & Kuyini, 2017), hence the focus of this study on rural education which is an issue of social justice in South African education research. There is no single reality or truth for critical paradigm, but there are multiple realities shaped by cultural, political, ethnic, gender and religious factors which interact with each other to create a social system just like interpretivism which can be explored by the interaction between the knower and the known (Okesina, 2020), hence the importance of critical and interpretivism paradigms for this study.

The interpretivism paradigm recognises humans as individuals having unique experiences and uses descriptions to interpret the meanings of individuals (Cohen et al., 2011; Pozzebon, 2004). Interpretivism and some aspects of critical paradigms were necessary to understand teachers' pedagogical approaches to the Electricity topic. Doolin (1998) argues for interpretive researchers to consciously adopt a critical and reflective stance to understand rural science teachers' pedagogical approaches to topics regarded as difficult in the science curriculum. A critical interpretive paradigm as an emergent perspective is advocated by various researchers (Deetz, 1982; Doolin, 1998; Pozzebon, 2004) because it emphasises communicative orientation, which implies interest in human understanding that implies hermeneutics and is the heart of interpretivism. Given the support, critical interpretivism was important for this study to critically explore teachers‘ pedagogical approaches during the Electricity topic lessons using VSRI, which encourage teachers to reflect on their teaching as they watch and analyse their approaches. For this study, I did not only want to interpret what was happening in the classroom, but to go further and understand how and why it happened the way it did, which is promoted by the critical aspect as argued by Doolin (1998).

Critical interpretivism served as the organising principle to which reality was interpreted in this research study (Babbie, 2011; Morgan, 2007; Pozzebon, 2004) because using interpretivism only was limited, as it is concerned with understanding and interpreting phenomena in society. Thus, the critical interpretive paradigm was used to interrogate the physical science teachers‘ approaches during the Electricity lessons, their pedagogical reasoning, and the factors that influence how they teach. The assumption for this study was that teachers‘ approaches are not only objective, as is the nature of physical science, but their experiences and perceptions shape what they know, how they know it and how they teach the topic of Electricity in the physical science subject. It is because of this complexity that using critical interpretivism was important, to critically analyse the multifaceted nature of teaching physics in rural secondary schools. The critical interpretive paradigm considers an understanding of the context in which any form of research is conducted as critical to the interpretation of gathered data (Thanh & Thanh, 2015), which was seriously considered in this study. The context of the study is discussed in detail in section 4.6, for the readers to engage, understand, and make sense of the findings.

Like any paradigm, critical interpretivism gives epistemological and ontological stances for this study, making it important to discuss my ontological, epistemological, axiological, and methodological standpoints. I situate myself within a relativist ontology which holds that the research problems have multiple realities that can be explored and meaning to be derived by the researcher through their interaction with the research participants (Okesina, 2020). Though a relativist, I am also influenced by historical realism because of my interest in the history of social realities for the attainment of social justice. As such, I use a dialogic - naturalistic methodology to gather information and make meaning of that information through my own thinking and cognitive processing informed by my interactions with participants – subjectivist epistemology. Lastly, I assume a value-laden and balanced axiology where I account for my bias and those of the participants in presenting a balanced report of findings (Kivunja & Kuyini, 2017; Okesina, 2020). My possible biases were communicated in section 1.2.1. Linked to my ontological stance, this study views the nature of teaching is complex and dynamic because it is subjective, guided by teachers‘ beliefs and values that are usually subjective despite physical science being considered objective. In this study, the unknown teachers' complex and dynamic approaches during the Electricity lessons were critically interpreted and analysed, to gain insight into their subjective experiences in a rural context.

Furthermore, epistemologically, knowledge is based not only on observable phenomena for this study, but also on subjective beliefs, values, reasons, and understandings (knowledge is constructed) (Aliyu et al., 2015; Ponelis, 2015). Hence, this study used VSRI and semi-structured interviews, in addition to observations, to reflect with teachers and further understand whether and how their beliefs and values influenced classroom practices and pedagogical reasoning. In the context of critical interpretivism, epistemology means teachers‘ classroom practices are understood within the rural contexts (social, political and economic contexts). Thus, teacher pedagogical knowledge is constituted by their lived experiences and is also based on subjective beliefs, values, reasons, and understandings (Aliyu et al., 2015). Considering the abovementioned epistemology, ontology, and axiology, critical interpretivism justifies the methodological procedures that were used in this study, as explained in section 4.5. The chosen methods correlate with critical interpretivism, as this study captured ‘insiders‘ knowledge through the use of classroom observation and semi-structured interviews. Additionally, VSRI provided the dialogic element to data generation methods, which encouraged self-conscious criticism (Okesina, 2020). The next section presents the research design which is consistent with the research paradigm.

4.3. Research design

The study used collective case study design because it is concerned with the examination of a particular case to provide insight into an issue rather than a case itself (Creswell, 2008; Denzin & Lincoln, 2005; Simons, 2009). Babbie and Mouton (2007) view research design as the plan or blueprint of how the research is to be conducted, to address the research questions and objectives of the study. They have identified three types of qualitative research designs, namely:

ethnography, case studies and life histories. While both designs are relevant, ethnographic and life histories were not suitable for this study because the former studies larger entities or units of analysis (such as communities, social settings, and cultural groups) and requires long stay in the research field for in-depth data collection, while the latter focuses on life development of one or more individuals (Babbie & Mouton, 2007). On the other hand, case studies are interested with a more clearly delineated entity (such as specific household, institution, or context), providing an in-depth investigation of the context (Babbie & Mouton, 2007; Yin, 2013).

Since this study was conducted in three rural schools in KwaZulu-Natal Province, in the natural teaching and learning classroom settings, it adopted a case study research design. Yin (2018) describes a case study as an empirical method to investigate a phenomenon in depth within its natural or real-world context. Creswell (2012) also raised a similar point when describing a case study as "an in-depth exploration of a bounded system (e.g., activity, event, or individuals) based on extensive data collection" (p. 465) and bounded implies the system is unique according to place, time, and other physical boundaries (Millan & Schumacher, 2010). The 'bounded system' in this study was a physical science teacher in a rural school. Case study design was considered necessary for this study because of the interface between science teaching and the rural context to which science is taught (Yin, 2018).

Within case study design, there are explanatory, exploratory, intrinsic, instrumental, and collective case study research designs (Denzin & Lincoln, 2005; Stakes, 2005). As mentioned above, a collective case study design was appropriate for this study because the three physical science teachers[16] were chosen not to study the teachers but their pedagogical practices and factors affecting these practices. Njie and Asimiran (2014) argue that a collective case study is when several cases are jointly studied to investigate a phenomenon, institution, person, population, or entity to understand a particular situation in depth. It is important to state that each physical science teacher was treated as an instrumental case but, when studied jointly, the collective cases were to unearth teacher pedagogical practices for the Electricity topic in rural schools, as suggested by Stake (1995) and McMillan (2012). The individual cases and collective case are also reflected in the analysis and discussion of findings in

[16] Rationale and criteria for choosing three schools and one teacher per school is explained in section 4.6.1

this study in Chapters 6 to 9. Each case consisted of one Grade 10 physical science teacher teaching in a rural school in Vryheid, KwaZulu-Natal Province and, studied jointly, this collective case study worked with three cases.

In this study, teachers were observed over a period of two weeks when teaching the topic of Electricity in Grade 10 rural physical science classrooms. Leedy and Ormrod (2015) suggest that a particular individual, programme, or event should be studied in depth for a defined period of time in case study designs. The observations were meant to watch and record teachers' live teaching of the Electricity topic and the approaches they used during the lessons, which were further examined and discussed with the teachers during the VSRI discussions and represent pedagogical reasoning. Importantly, the focus of the collective cases was on the nature of teaching and classroom interactions or lack thereof, and the pedagogical approaches used by teachers in the teaching of the Electricity topic. The phenomenon in focus for this study was the physical science teachers' pedagogical approaches and the factors that influence the choice and use of those approaches for the topic of Electricity.

4.4. Research approaches

There are three main research approaches usually employed in educational research: qualitative, quantitative, and mixed method research approaches (Creswell, 2012; McMillan, 2012). Qualitative research is characterised by understanding aspects of social life, and its methods dominantly produce words rather than numbers as data for analysis, while the quantitative research approach aims to give a measure of something hence dominated by numbers (McMillan, 2012; Patton & Cochran, 2002). Qualitative and quantitative approaches can be combined to give rise to a mixed method research approach, which is associated with collecting and analysing data by using both qualitative and quantitative research approaches in one study (Creswell, 2012; McMillan, 2012). Within mixed methods, there are different methods researchers can choose from, depending on the focus of the study. Despite their usefulness, quantitative and mixed method approaches were not appropriate for this study because the purpose was to explore and understand teachers' lived experiences with science teaching in rural school contexts instead of taking any measurements. Therefore, this study used the qualitative research approach due to its affordances for in-depth exploration of a situation or process, to gain insightful understanding of that situation (Creswell, 2012). The qualitative research approach is naturalistic, interpretative, and encourages critical interpretation of social actions (Njie & Asimiran, 2014; Ritchie et al., 2013). The naturalistic and critical interpretation of qualitative research approach links with the methodological and the ontological principles of critical interpretivism paradigm and collective case study.

When understanding social actions from their context, the researcher considers the natural settings of social actors and takes the perspectives and accounts of research participants as a starting point (Denzin & Lincoln, 2004; Freebody, 2003). Similarly, this study explored, described and critically interpreted teachers' pedagogical approaches to Electricity topic in rural Grade 10 classrooms from the observed classroom practices, and further engaged with the teachers to understand their accounts of teaching physics in a rural context. So the qualitative approach was used to reconstruct and understand teachers' pedagogical approaches and the reasons teachers used certain approaches to teach the Electricity topic. The qualitative approach enabled me to collect detailed and multi-purpose qualitative data from individual cases. With this consideration, the findings cannot be generalised to a larger population but will help to understand the social actions in similar settings (Anderson, 2010).

4.5. Qualitative Data Generation

Research data generation methods are techniques used by researchers to generate information about the specific subject under study (McMillan, 2012). Qualitative data is generated in several ways, including the use of interviews (structured or unstructured interviews, in-depth individual and focus group interviews), observations (participant and non-participant observation), and document analysis (personal documents and field notes) (Babbie & Mouton, 2007; McMillan, 2012). Given the qualitative nature of this study, semi-structured non-participant classroom observations, video-stimulated recall interviews and in-depth individual interviews generated research data for the study.

4.5.1 Semi-structured non-participatory classroom observations

Creswell (2012) describes observation as the process of gathering open-ended, immediate information by observing people and places at a research site, and this method can be structured, semi-structured, and/or unstructured observations. In a structured observation method, the researcher knows in advance what to look for and has observation themes worked out in advance (Cohen et al., 2011). It was not suitable for this study because I sought to unearth teachers‘ lived experiences from the natural classroom teaching setting, which is usually not as structured as expected. The unstructured observation method is more flexible because the observer goes into a situation and observes what is taking place before deciding on its significance for the research. This method was also not suitable for this study, because I had predetermined the focus of the study on teacher pedagogical practices (Cohen et al., 2011). Consequently, semi-structured observation was appropriate for this study because I had to collect data to illuminate teacher pedagogical practices in a far less predetermined or systematic manner, while allowing me to consider important contextual factors that may influence the interpretation and use of the results (McMillan, 2012). Specifically, non-participatory semi-structured observation played a crucial role as I video recorded all teachers‘ actions in the classrooms to ensure that nothing was missed as compared to only writing notes about what was happening in the classroom. This decision was further informed by the paradigm, researching a phenomenon within its natural setting, and unearthing teachers‘ practices within their teaching context.

As a non-participant observer, I stood silently at the back of the classrooms, capturing the teaching processes as they progressed. Stationed at the back of the classrooms, I held the video recorder, silently recording the teaching practices and focusing on the teachers‘ classroom interactions with the learners, writing on the chalkboard, demonstrations, movements, talk, and explanations. Teachers‘ and learners‘ faces were blurred in the analysis of the video-recorded classroom practices for confidentiality and anonymity purposes. The semi-structured non-participant classroom observation was important for this study because it “yields firsthand data without the contamination that may arise from tests, inventories, or other self-report instruments” (McMillan, 2012, p. 163). Moreover, this data generation method yielded interesting results as people do not always do what they say they do during interviews (Cohen et al., 2007), making it appropriate to fully understand the teaching of the Electricity topic as it happens in a normal day-to-day classroom context. Moreover, some of the advantages of this observation method are that it provides an opportunity to record information and actual behaviour as it happens in the classroom context, to study actual teachers‘ behaviour, and to study an individual‘s difficulty with verbalising their ideas (Creswell, 2012). Thus, classroom observations gave me opportunities to consider important contextual factors, such as classroom sizes, official language of instruction barriers, poor and/or lack of school resources, among other factors that influenced teachers‘ pedagogical practices in the observed lessons. These observed contextual factors helped in responding to the third research question of this study. Nevertheless, the classroom observation data helped to respond to the first research question of this study.

Notwithstanding the opportunities provided by classroom observation, it is important to highlight that though I was standing at the back of the classroom with the video recorder, my presence was still acknowledged by teachers and learners. During the lessons, some teachers made some content and procedural mistakes which, even though not sure, could have been attributed to my presence. Consequently, when analysing data, I noted some genuine minor mistakes by teachers which could have been caused by the observation method leading to teachers and learners feeling uncomfortable with a stranger in their space; leading them to behave in a way that they think I (the observer) expects them to behave. Notwithstanding this observation, Creswell (2012) argues that some teachers might act during classroom observations but also acting might not last for a while, as actors can go back to their ‘normal‘ behaviours after some time. In addition, most learners appeared shy to ask and answer questions during the teaching and learning processes, possibly because of the outsider in their learning space. In this study, physical science teachers and their non-participant learners were observed looking at the video recorder occasionally, then quickly changing direction to focus on their teaching and learning tasks. Thus, the two weeks spent in the field with teachers might have given them enough time to go back to their real normal teaching practices should it happen that they initially acted.

4.5.1.1. The process of classroom observations

Overall, 10 classroom lessons were observed from the three teachers and all 10 lessons were video recorded and transcribed verbatim for analysis purposes. In all the lessons, the video recorder was switched on from the beginning of the lesson until the last second of each lesson. When recording the lessons, the video recorder was always positioned towards the teacher and the recorded lessons differed in length, lasting between 26 and 52 minutes. Recording all sections of the lessons was done to capture both teacher talk and teacher approaches to the teaching of electricity-related concepts, including non-verbal communication by the teacher. From the video-recorded lessons, I focused on teachers‘ presentations of the content of the Electricity topic, that is, the use of (or lack thereof) links to build scientific knowledge, including the use of representations (micro/macroscopic and symbolic), the relevance and adequacy of content to Grade 10 level (curricular saliency), teachers‘ considerations of learner prior knowledge on the topic, teachers‘ considerations of the difficult concepts within the topic and how they approached it (see Observation schedule in Appendix 7).

The strategy of video recording assisted with partialness of my view and overcame the tendency towards recording only the frequently occurring events, since observations tend be selective and objective in nature. Video recording the lessons helped minimise my disturbance of the lessons and provided an opportunity to observe the lessons several times to facilitate in-depth analysis. Also, video recording enabled viewing and re-viewing of the various practices, interactions, and participation in the classrooms as part of the analysis process and understanding the different interactions and practices during the teaching and learning process. Additionally, video recording the classroom observations was useful when conducting video-stimulated recall interviews[17] with teachers, as I allowed teachers to observe the chosen video clips of them teaching, with the aim of facilitating their pedagogical reasoning for the observed pedagogical choices, as required by the critical interpretivism paradigm and by the frameworks discussed in Chapter 3. Data from classroom observation lessons were used to answer the first research question of this study. The recorded lessons per teacher are outlined in Table 4.

[17] Video-stimulated recall interviews are detailed in the section 4.5.2.

Table 4

Summary of the observed videos (see Appendix 8 for a sample of observed lesson**)**

Teacher	Lesson Topic	Lesson concepts/tasks	Time
Sipho	**1**. Electric Circuits	I, V, R	35:21 mins
	2. Connections on electric circuits	Ohm's Law (I, V, R) Series and Parallel resistors Calculations	32:23 mins
	3.Series and Parallel circuits	R, V, I_T Classwork on simple and complex circuits	40:06 mins
Thando	**1**. Simple circuits	Electric current Potential difference (battery, lost volts, & emf) Resistance (internal resistance)	33:12 mins
	2. Electric circuits	Ohm's Law (V,I,R); Calculations Electric Circuit components demonstration	48:48 mins
	3. Electric circuits	Series resistors (connection) Parallel resistors (connection); Calculations	35:37 mins
	4. Electric circuits	Calculations on series and parallel connections *classwork	30:01 mins
Amanda	**1**. Electric circuits	Components of a circuit (I,V,R) –instruments Calculations (W,Q,V,I,t) *classwork	52:17 mins
	2. Simple circuits	Series and Parallel connection (demonstration) Calculations	52:21 mins
	3. Simple and complex circuits	Series and parallel resistors – calculation	26:22 mins

4.5.2 Video-Stimulated Recall Interviews (VSRI)

As part of triangulating teacher understanding of their pedagogical practices, this study also used video-stimulated recall interviews (VSRI). VSRI is a research technique where teachers are given an opportunity to "view a video sequence of their behaviour and are invited to reflect on their decision-making processes during the videoed event" (Nguyen et al., 2013, p. 1). This technique was about using stimulus (recorded video) to trigger teachers' thought processes associated with the teaching of the Electricity contents from the observed video clips (Gass &

Mackey, 2000). Though directly linked to the observation, VSRI expounds the self-reported (through interviews) and observed behaviours. It this by giving teachers a chance to observe themselves performing and then immediately explaining what was important to them at the time, and why they chose to behave as observed. This strategy was important to get teachers‘ pedagogical reasons, which helped to answer the second research question of this study.

After video recording teacher‘s practices during the lessons, I watched the recorded videos with my supervisor and I identified episodes[18] (video clips) to discuss with the teachers, which were confirmed by my supervisor, as part of teachers‘ reflections and guided by the focus of the study. It was important to select episodes to discuss with the teachers, to attend to the focus and research questions of the study. While I selected episodes to discuss with the teachers, I made them aware of the selected episodes we were going to discuss, so that they also paid attention to them as they watched the whole videos. It was important to do this so that teachers had an opportunity to observe themselves and make sense of what they were doing while teaching, while also helping them to relax when they pre-watched the whole recorded video before discussing the pre-identified episodes. Also, the decision to alert teachers to the identified episodes was so that they could think of these episodes in relation to the whole lesson(s) while reasoning on their pedagogical practices exposed in these episodes. All the identified and discussed episodes are presented in Chapters 6 to 8. The duration of each teacher‘s VSRIs is shown in Table 5.

Thus, VSRI yielded both insightful and useful data for examining live teachers‘ practices and the nature of interactions with learners during the Electricity topic lessons. This was important in order to understand their ‘interactive‘ thoughts, decision-making processes, and behaviours towards teaching and learning of the topic of Electricity (Nguyen et al., 2013). Despite its usefulness, I acknowledge that VSRI has the potential to elicit anxiety and distress in the participants (Paskins et al., 2017). However, in this study, teachers showed an interest in VSRI and were appreciative of this method. Instead of being anxious, teachers were happy to participate to improve teaching practice by reflecting with someone on their teaching. I did the VSRI‘s with each teacher in the science laboratory with Thando; in the office of the deputy

[18] Episodes are defined in Chapter 5 and a clear description of how episodes were identified is detailed in Chapter 5.

principal with Amanda; and in a storeroom with Sipho. All the VSRI‘s were conducted in conducive and quiet environments without any disturbances during the process. Table 5 presents interview information for semi-structured individual interviews and VSRI.

Table 5

Interview information with each participant (see Appendix 11 for a sample of interview)

Participants	Time Taken	Type of interview
Sipho	20 mins, 51 secs	Semi-structured Individual
Sipho	38 mins, 50 secs	VSRI
Amanda	28 mins, 10 secs	Semi-structured Individual
Amanda	67 mins	VSRI
Thando	27 mins, 21 secs	Semi-structured Individual
Thando	87 mins, 13 secs	VSRI

Note: VSRI = Video-Stimulated Recall Interview

4.5.3 Semi-structured interviews

In addition to the unstructured non-participant classroom observations and the video-stimulated recall interviews, this study used semi-structured interviews which specifically focused on profiling teachers (teacher biographies) while also illuminating factors shaping teacher classroom practices. The interview method of data generation required a special skill to collect quality data in which questions were asked orally and participants‘ responses recorded verbatim, as suggested by McMillan (2012). This study employed semi-structured interviews which do not have predetermined structured choices; rather they are open-ended yet specific in intent, allowing individual responses (McMillan, 2012). Semi-structured interviews are reasonably objective yet allow for probing, follow-up, and clarification and it was the most suitable type of interview for this study. Unstructured interviews, however, are open-ended, broad, and difficult to conduct because they are reasonably subjective and thus were not appropriate for this study (McMillan, 2012). Similarly, the structured interviews were not suitable for this qualitative case study because they are mostly used in quantitative data collection as they involve pre-prepared sets of questions (usually in the form of questionnaires) and these questions are asked in the same order to all participants, giving participants‘ choices from which an answer is selected (Creswell & Creswell, 2017).

This study used semi-structured individual face-to-face interviews with the teachers to understand their general views about the teaching and learning of physical science, and the topic of Electricity in particular, which might influence the teachers‘ teaching approaches. The semi-structured individual face-to-face interviews were chosen because they allow a close focus on specific issues of concern, such as factors influencing teacher pedagogical approaches for physical science, including the Electricity topic, training experiences, and experiences of teaching physical science in rural schools. Furthermore, Grade 10 physical science teachers were interviewed individually because they are ‘key‘ participants, who are knowledgeable on the teaching of the topic of Electricity (McMillan, 2012). During the interviews, teachers‘ responses were audio recorded with their permission and later transcribed verbatim for analysis. Audio recording the interview sessions allowed me to pay attention to participants' responses and prompt for more information where necessary, as compared to taking notes while the participant is talking. In addition, audio recording the interview helped me focus on teacher‘s non-verbal responses also, and to be conscious and attentive to the participants‘ body language which possibly represented their attitude and feelings regarding the phenomena being researched (Creswell, 2012; McMillan, 2012).

Due to time constraints in the field, the in-depth individual interviews were conducted after the last observed lesson of each participant teachers. Through these interviews, basic background information about each teacher was gathered. From all the interview sessions, I had baseline questions where I asked teachers‘ views of science teaching; experiences of physical science, including the Electricity topic teaching and learning in rural schools; qualifications and other demographic issues; and were also guided by what transpired from observed classroom teaching. Overall, three interviews were conducted with all participants (one interview per teacher). Some teachers had more information to share with me, while others had little to say, but all teachers were probed where clarity was needed. The talking characters of teachers lead to the interviews being different in terms of lengths, agreeing with Irvine‘s (2011) point that there is often a variation in the duration of interviews because of some participants being more outspoken than others. However, all interviews were within the margins of 20 to 30 minutes (see Table 5). Table 5 above present the time taken to complete each interview with each participant. Part of the semi- structured interview data was used in answering the third research question of this study. Similar to the VSRI‘s, I conducted each teacher‘s semi-structured interviews in the science laboratory with Thando; in the office of the deputy principal with Amanda; and in a storeroom with Sipho. All semi-structured interviews were conducted after school hours.

4.6. Research sampling

McMillan (2012) refers to a research sample as a group of participants from whom research data are to be collected, and in qualitative research participants can be selected purposively, dimensionally and/or based on convenience sampling, to name a few. Echoing the same view, Johnson, and Christensen (2008) assert that during sampling, the researcher selects a portion of the population to represent the entire population under investigation. This study therefore used purposive sampling (Babbie & Mouton, 2007) located within a group of non-probability sampling techniques, to choose participants based on judging their typicality or possession of the characteristics being sought (Cohen et al., 2011). From the purposive sampling, this study is located within the criterion sampling strategy to select participating teachers, as I selected participants based on identified characteristics such as being a Grade 10 physical science teacher, teaching in the selected rural high schools in Vryheid, and being willing to participate in this study.

Consequently, I ensured that participants had sufficient experience (at least 5 years[19] of Grade 10 physical science teaching by the time of data generation) with what was being studied (McMillan, 2012). Importantly, all the teachers involved in this study had more than 10 years of teaching experience; teacher biographies are presented in Table 7. The rural secondary schools were selected because they offered physical science at FET level and were located in the area

[19] Maclellan and Soden (2003) define teachers with seven years of experience as being knowledgeable, experienced teachers who are in possession of an organised body of conceptual and procedural knowledge. On the other hand, Rice (2010) views those teachers with five years of experience as being effective in schools, unlike those with less than two years of experience (novice teachers). So, in this study all teachers had more than 10 years of physical science teaching experience and were considered experienced teachers with adequate content mastery relevant to the South African Grade 10 physical science curriculum.

described as rural in Vryheid town, KwaZulu-Natal Province. These schools are quantile 1[20] and no-fee paying schools, fully subsidised by the Government. One Grade 10 physical science teacher was selected per school and each school had only one physical science teacher for Grade 10. Only one school had a different physical science teacher for Grade 12; the other schools had one physical science teacher teaching from Grade 10 until Grade 12. I thought it was advantageous to have teachers that taught physical science from grade 10 to 12, because the current practices could be used also in grades 11 and 12. Moreover, all the selected teachers were English First Additional Language (EFAL) speakers as their home language is IsiZulu and two of the teachers grew up and live in the communities where their schools are located. I detail the schools and teachers in the following sections.

4.6.1 Participating schools

It is important to understand the context in which this study was conducted to know whether and how the context shaped teachers‘ thinking and teaching processes. As mentioned earlier, this study was conducted in three rural high schools[21] in Vryheid town, KwaZulu-Natal Province, and I worked with the only Grade 10 physical science teachers in each school. All the selected schools were from the Zululand municipality and located approximately 25 to 55 kilometres away from Vryheid town, KwaZulu-Natal Province of South Africa. The language spoken mostly in the three selected schools is IsiZulu which is also a home language for all observed teachers and learners, while English is the official language of learning and teaching (LOLT). While this is the case, I observed that most of the teachers used the learners‘ home language, especially for giving instructions, rephrasing explanations, giving analogies and other tasks during teaching. Two of the three schools (Sakhisizwe and Zabalaza meaning ’*we building the nation*‘ and ‘*to struggle*‘ respectively) are classified as quintile 1 schools (deep rural schools) and the third school (Siyaphumelela – meaning ‘*we succeed*‘) is classified as a quintile 2 school. The reason for the two quintile 1 schools is because of their location within forests and learners pass

[20] In South Africa, schools are ranked into five quintiles, with quintile 1 representing the poorest schools and quintile 5 representing the most affluent schools (White & Van Dyk, 2019).

[21] For purposes of identity protection of the three participating schools, pseudonyms are used when reporting the findings to ensure the anonymity of the participant schools. Thus, throughout this thesis the schools are referred to as Zabalaza High School, Sakhisizwe High School, and Siyaphumelela High School, which are all pseudonyms referring to the participating schools.

by these forests when going to or from school. There is one road from town to these two schools. On this road from town, approximately 15 km away from Zabalaza High School, there is an informal road which makes it difficult to travel through during rainy seasons. Though the third school (Siyaphumelela High) is a rural school and isolated, it is located next to the main road to town with relatively better sources of transportation (taxis, buses, and private cars) than the first two schools. Table 6 summarises the characteristics of the three participating schools.

Table 6

Table showing participating schools and their characteristics

Characteristic / Schools	**Sakhisizwe High**	**Zabalaza High**	**Siyaphumelela High**
Located in semi-rural area	×	×	✓
Located in deep-rural area	✓	✓	×
Distance from Vryheid Town	+/- 40km	+/- 55km	+/- 25km
Availability of science laboratories / functional	✓ / ×	✓ / ×	✓ / ×
Science learners‘ textbooks / alternatives	None / relies on examination guide and teacher‘s notes	About 4 learners per textbook / relies on examination guide and teacher‘s notes	1 textbook per learner / also relies on teacher‘s notes
Availability of school library / functional	× / ×	× / ×	× / ×
Overcrowded classrooms	×	✓	✓
Practice of code-switching	✓	✓	✓
Kitchens for National School Nutrition Plan (NSNP) using firewood	✓	✓	✓
Flushing toilets	×	×	×
Learner population—Black South African	✓	✓	✓
Cultivated school garden	×	✓	✓

Teacher Thando, whose school (Siyaphumelela High School) is closer to the main road to town, reaffirmed that her school is rural because of its location and the learners it attracts are mostly from rural communities. So from teachers‘ responses on the location of their school, it was clear that all the schools are located in rural spaces, though different opportunities and disadvantages were used to conceptualise the context of each school.

Thando‘s and Sipho‘s learners (from Siyaphumelela High School and Sakhisizwe High School respectively) used to walk long distances to and from school, leading to a high rate of latecomers and prohibiting extra classes after school hours. However, ever since the bus transportation initiative, learners get to school at 7:30 am and the bus transports them back home at 2:30 pm. This still presents challenges for Thando as she cannot schedule Electricity practical work after school hours. For example, there were learners that attend Sakhisizwe and Siyaphumelela high schools that used to walk 7-10 km to school, a reason the government provided buses to transport most of these learners to and from school. Learners who attend Zabalaza High School continue to walk up to 7 km to the school, and are not provided with bus transportation. As a result, some of the learners who arrived at school after 8 am were asked to stand outside the school gate which was closed at 8 am (see Image 1 of Photograph 3 for Zabalaza High School). From the observation of the schools, I noticed that Zabalaza and Sakhisizwe high schools lack science teaching support materials and textbooks, and lack sanitation, and water (see Image 2 of Photograph 3 showing learners carrying buckets of water to school during school hours and Image 1 of Photograph 2, Image 6 of Photograph 3, and Image 6 of Photograph 4, showing toilets which have no running water inside).

All three schools are beneficiaries of the National School Nutrition Programme[22] (NSNP) which provides food for the learners, and the food is cooked in an open space using firewood (Image 8 of Photograph 3) due to lack of kitchen space for Zabalaza High School, while Sakhisizwe and Siyaphumelela high schools use gas stoves in their newly built school kitchens. The three government public schools mirror a shared understanding about the unbearable conditions of

[22] National School Nutrition Programme (NSNP) is “a national programme managed by the Department of Basic Education, targeted at poor communities, whose objectives are to contribute to enhanced learning capacity through school feeding; promote and support the implementation of food production initiatives in schools; and strengthen nutrition education for school communities” (DBE, 2018, p. 6).

educational spaces (classrooms and science laboratories) and support educational spaces (kitchens, gardens, toilets). As such, these schools have similarities and differences even though located in the same district, which addresses the complexity of rurality. Similarities in the schools were the learner population that comprised only Black[23] South African learners coming from different socio-economic backgrounds. Zabalaza and Siyaphumelela high schools were overcrowded as they each had more than 80 learners in one physical science classroom, which made it difficult for the teachers to move around the classroom. However, Sipho in Sakhisizwe High School had a relatively manageable number of learners (less than 40 learners in one classroom). Photograph 3 shows a pictorial representation of Zabalaza's High School contexts.

Photograph 2:

Sakhisizwe High School

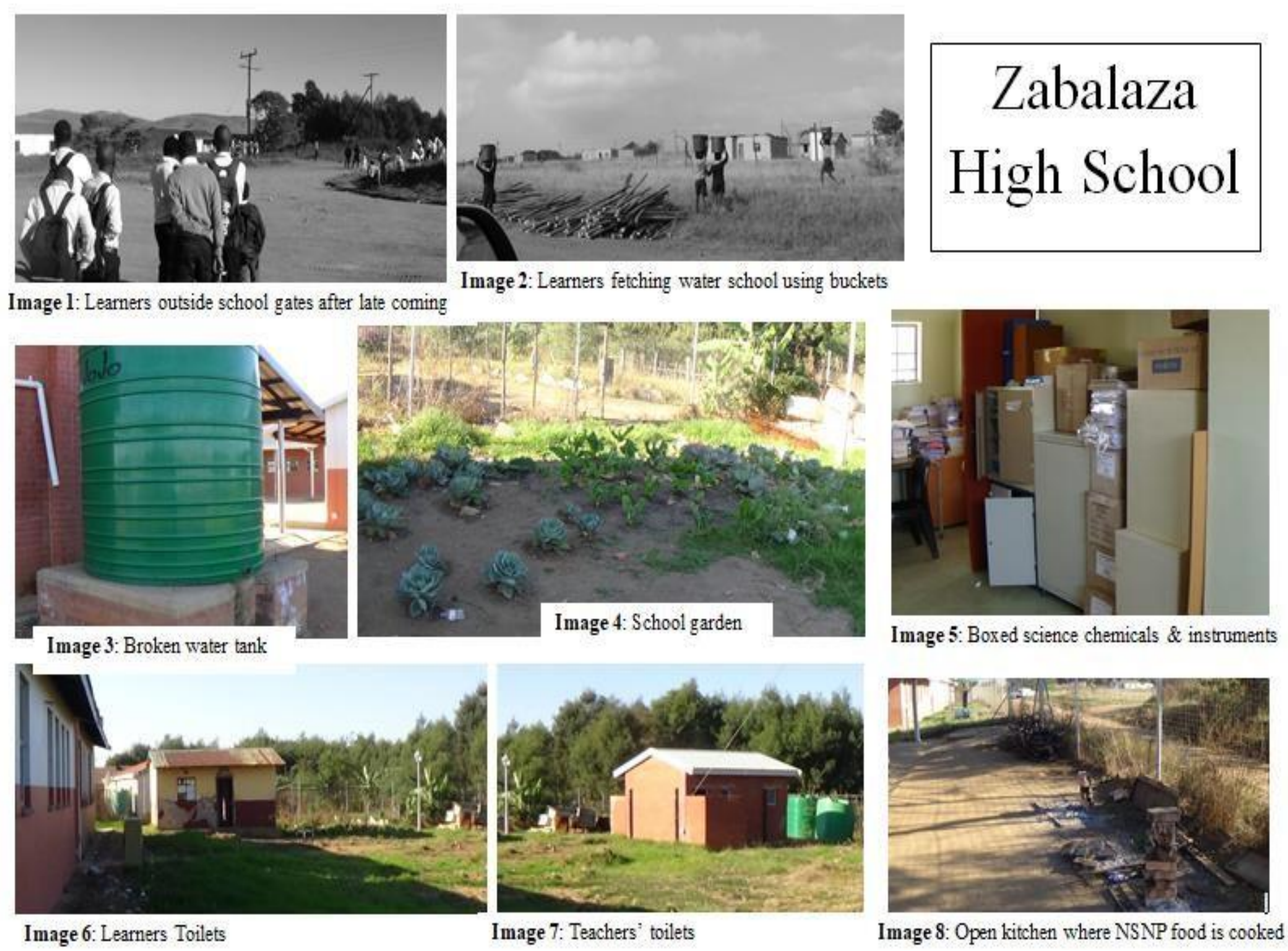
Image 1: Science Lab used as a Grade 12 classroom

Image 2: Learners' toilets

[23] Historically, Blacks includes Coloureds and Indians, but in this section Blacks exclude the Indians and Coloureds.

Photograph 3

Zabalaza High School



The 'core science educational space' (science laboratory in Image 1 of photograph 2) in Sakhisizwe is appalling because it is unmanaged, dysfunctional, lacks chemicals and instruments, and it is used as a classroom space for teaching rather than a science laboratory. While Zabalaza and Siyaphumelela high schools had materials (apparatus) for science practical work; some of it was still in boxes (Image 5 of Photograph 3) and some were stored in storerooms (Image 1 of Photograph 4). Zabalaza's Electricity kit was only opened when I got to the school for observation and Siyaphumelela's teacher (Thando) only used some of the apparatus to show components of an electric circuit. Photograph 4, illustrates Siyaphumelela High School's contextual environment.

Photograph 4

Siyaphumelela High School

Image 1: Organized chemical store room **Image 2:** Classroom roof top **Image 3:** School garden

Image 4: Unexploited TV in the classroom **Image 6:** Locked learner's toilets

All three schools had two separate pit toilets, one used by teachers only and the other by learners. Images 2, 6, and 6 from Photographs 2, 3, and 4 respectively show the infrastructural deterioration of learner toilets, especially in Sakhisizwe and Zabalaza high schools. None of the schools had effective or functional libraries, making the teacher and their creativity the source of science information in the school, especially when considering that the idea of school computers is foreign in all three schools. This highlights the importance of teachers' effective teaching approaches for physical science, including topics like Electricity which are already perceived as difficult topics.

4.6.2 Participating teachers

There were three Grade 10 physical science teachers that participated in this study; two teachers were females and one male teacher. All were classified as Black South African and IsiZulu home language speakers. Each teacher's biographical information is presented in Table 7 and only significant information is presented in the table. The sample size for this study was not influenced by age or gender, but rather by teachers who teach Grade 10 physical science classes in Vryheid rural schools, KwaZulu-Natal province. As evident in Table 7, teachers also have other responsibilities in the school, notably Amanda who is deputy principal at her school and she mentioned that this position requires a lot of her time which takes some of her teaching time away.

Teacher Sipho initially trained as a mathematics teacher; even when he studied Honours, it was in mathematics. He studied engineering, specialising in Electricity, which was advantageous for the high school Electricity content. Nevertheless, how this content is then translated into teachable forms was an important aspect for this study because the teacher did not train as a physical science teacher, as indicated in Table 7. On the other hand, teacher Amanda was trained as a senior phase teacher specialising in natural sciences and mathematics, even though she was teaching the FET phase - Grade 10 content, when observed in this study. This teacher mentioned that even though she was trained for Grades 7-9 natural science, she has attended workshops (teacher development trainings) to prepare her for upper grades such as Grade 10 physical science.

Similarly, teacher Thando was also trained as a natural science specialist for senior phase (grades 7-9), though she was teaching the FET phase (Grade 10) when observed in this study. In her early years of teaching practice, Thando confirmed that she taught natural science at senior phase until she was asked to teach physical science at FET (grades 10-12), even though she alternates with another teacher for Grade 12 physical science teaching. While it is a 'normal' practice in South Africa for a teacher to teach in a phase they were not trained to teach in, it was still concerning that none of these teachers were trained to teach physical science at FET level, including the content knowledge, pedagogical knowledge and skills for sharing Electricity content knowledge. Teachers Amanda and Thando could be classified as off-phase teachers—teaching in a phase they were not trained to teach in. The 2010 TIMSS report noted that about 47% of South African physical science learners were taught by teachers without teaching degrees. Though this is not the case for this study, the three teachers could arguably be classified as not qualified to teach physical science FET. The biographical information of participants is presented in Table 7.

Table 7

Selected Grade 10 physical science teachers' biographical information

Criteria	Sipho	Amanda	Thando
Participating schools (*all rural government schools*)	Sakhisizwe High School	Zabalaza High School	Siyaphumelela High School
Teacher's citizenship or country of birth	South Africa	South Africa	South Africa
Gender	Male	Female	Female
Physical Science TE	14 years	13 years	23 years
Teacher qualification	NPDE / Electrical Engineering / Honours specialising in Mathematics	Senior Phase Teaching Diploma / ACE	Teaching Diploma (Inter/Sen) / ACE
Subject specialisation at university or college	Mathematics	Natural Science / Mathematics	Natural Science (Inter/Sen)
Subjects currently teaching	Physical Science / Technology	Physical Science / Natural Science	Physical Science / Natural Science
Administration responsibilities	Class teacher	Deputy principal (SMT) / class teacher	Class teacher / SGB member
LOLT	English (FAL)	English (FAL)	English (FAL)

***Key:** PGCE=Postgraduate Certificate in Education; FAL=First Additional Language; ACE=Advanced Certificate in Education; PG=Postgraduate; TE=Teaching Experience; LOLT=Language of Learning and Teaching; SMT=School Management Team; NPDE=National Professional Diploma in Education; Inter/Sen=Intermediate and Senior phase; SGB=School Governing Body*

4.7. Ethical considerations: Accessing the research site

Ethical considerations are critical in social science research, especially when research is done with human beings. As such, ethical processes were followed accordingly prior, during, and post data collection for this study. Firstly, I applied for permission to access and work with the rural schools in Zululand municipality focusing on those around Vryheid town and permission was granted by the KwaZulu-Natal Department of Education (see Appendix 2). I then applied for, and obtained, ethical clearance from the Human Research Ethics Committee of Wits University with the protocol number H19/03/35 (see Appendix 1). The departmental permission and university clearance were both taken to the Zululand District where the selected schools are located to notify the district management of the research activity and then individual schools were approached. Within the schools, principals were furnished with information letters about my study and I requested their permission to work in their schools with their Grade 10 physical science teachers (see Appendix 6).

I further explained the study in person to the principals and they consented in writing, allowing me to conduct my research study on their school premises. The school principals then introduced me to the respective Grade 10 physical science teachers, with whom I discussed the purpose of my research and ways of data generation for this study and then requested their voluntary participation through the teacher‘s consent form (Appendix 5). Teachers consented to be part of this study and further agreed to be observed and video recorded while teaching lessons on the topic of Electricity. Teachers also agreed to participate in the VSRI and semi-structured interviews after the observed lessons and the interviews were scheduled for after school hours, including the video stimulated recall interviews. Given that most Grade 10 learners are minors (generally below the age of 18 years) and were going to be observed being taught, I also sought permission from them and from their parents as minors (see appendices 3 & 4), and it was granted. For both teachers‘ and learners‘ rights of withdrawal from participation, the consent and assent forms indicated that the participants were free to withdraw at any stage without any negative effect on them or the school.

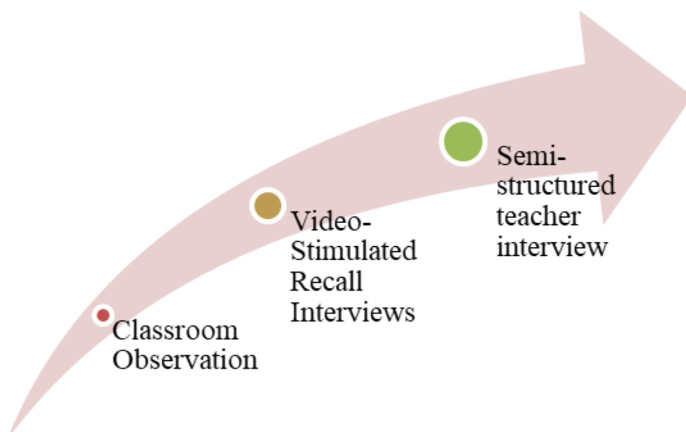
4.8. Data generation process

After all ethics protocols had been followed, I visited and worked with the schools. All the schools are in a rural area and being a rural area, it had its challenges because there were limited schools I could choose from. Also, the area has three high schools that can be regarded as rural schools or located in/or near rural areas. All three schools are located linearly in space in relation to each other. The first school, Siyaphumelela High School is located exactly 30 kilometres away from the second closest school, being Sakhisizwe High School. Then Zabalaza High School is exactly 11 kilometres away from Sakhisizwe High which makes Siyaphumelela High 41 kilometres away from Zabalaza High. This information is important as I singlehandedly moved between these three schools to observe lessons daily. Because of timetable clashes, I negotiated with the teachers to either delay some of their Electricity lessons or bring them forward before normal timetable slots so that I could also observe these lessons.

I would observe three teachers in one day. I had to arrange with the teachers so that I would be able to observe all of them in a day since the schools are far apart. By the end of teaching and learning of the topic of Electricity, I had observed a total of 10 lessons for all teachers combined and these lessons are analysed and discussed in Chapters 6 to 9. The observed lessons helped shape the individual interviews with teachers and the video-stimulated recall interviews. The actual process of data generation was not linear as I had imagined it at the proposal stage of this study in Figure 6 but was a complex process as seen in Figure 7

Figure 6

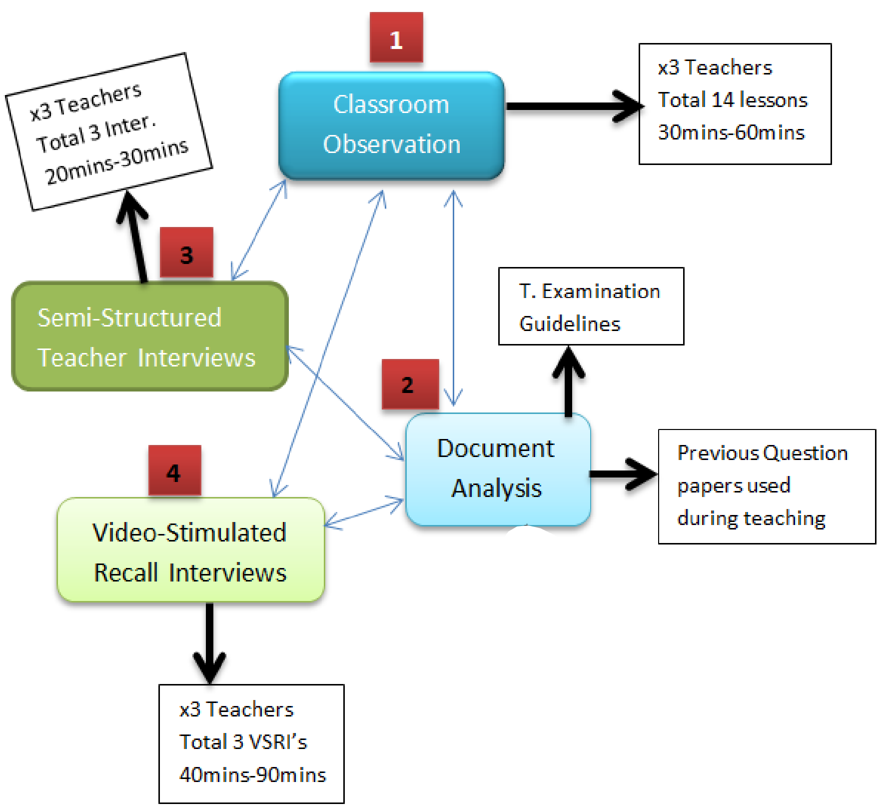
Envisaged process of data generation



Data collection was a complex process since I collected the data in two phases. The first phase of data collection was in May/June 2019 and the second phase in July/August 2019. In the first phase, I observed, and video recorded a total of 10 lessons on the topic of Electricity. Time frames for each lesson differed, as indicated in Table 4. In the observation processes, I obtained the teaching examination guidelines that teachers were using. Informed by classroom observation and the teaching examination guidelines, I then conducted semi-structured interviews with each teacher and the interviews ranged from 20 minutes to 30 minutes, as seen in Table 5. After this process, I watched the recorded lessons and worked with my supervisor to identify teaching episodes that suited the purpose of this study. After the episode identification, I went back to schools for phase two of data collection and allowed teachers to watch their teaching practices in the identified episodes and teachers reflected on these while giving their pedagogical reasoning. Teacher's recorded videos were saved on a USB and a copy of observed videos was shared with respective teachers. These video-stimulated recall interviews took between 40 and 90 minutes (see detailed information in Table 5). The VSRIs were also informed by documents such as teachers' examination guidelines as used during the observed lessons. Teachers Amanda and Sipho constantly referred to documents such as, examination guidelines and previous question papers during their classroom teaching. Though document analysis was not part of my research methods, however it was important to analyse and refer to the examination guidelines and previous question papers including the requirements by CAPS on Electricity topic teaching during the semi-structured interviews and VSRI's because these documents shaped teachers' classroom practices. Figure 7 illustrates the complex process of data collection for this study..

Figure 7

Actual data generation process



4.9. Data organisation and process of analysis

Qualitative data organisation and process of analysis refers to the order brought by the researcher into data, structuring and meaning-making from generated data. The generated data for this study included classroom observation data (observation transcripts), video-stimulated recall interviews (VSRI transcripts), and semi-structure individual interview (interview transcripts). Generated data was analysed in chapters 6 to 8 and discussed in chapter 9. The following sections details the process of meanings creation from raw data, from how data was organised, analysed, and discussed to address the objectives and research questions of the study.

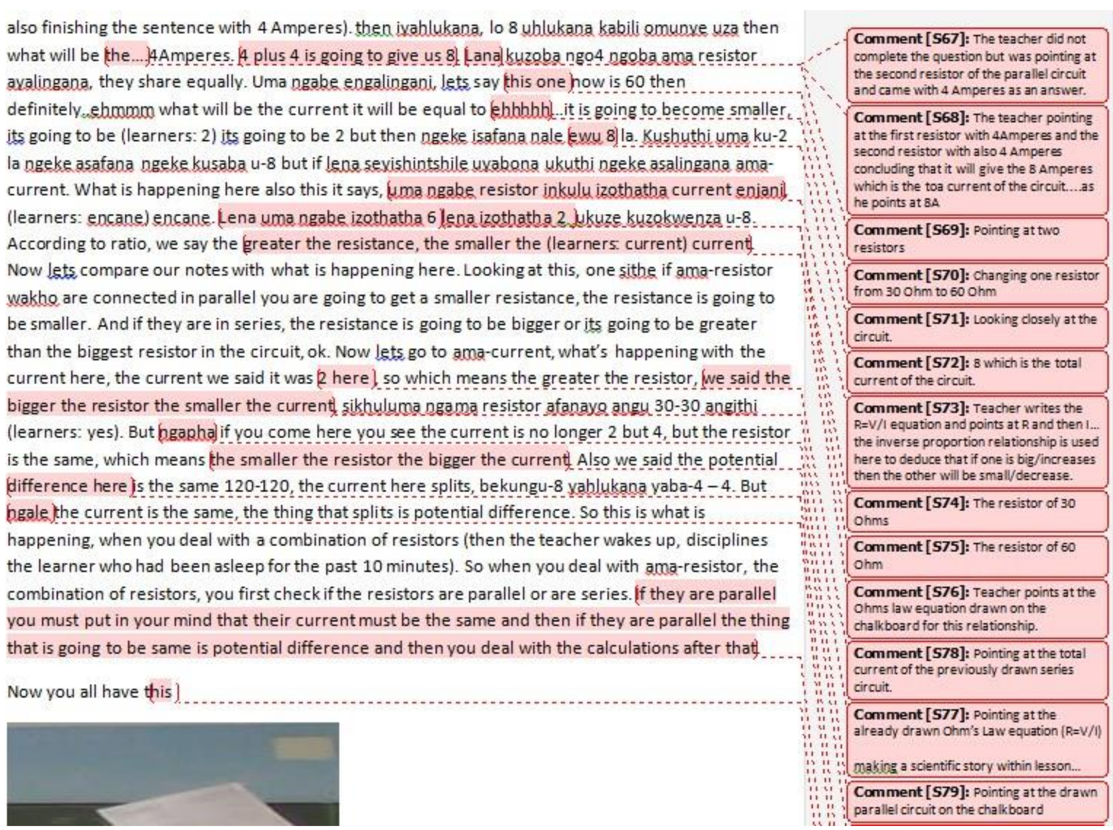
4.9.1. Data transcription and organisation process

I used Creswell‘s (2009) six steps for data organisation, to guide with the organisation of data, and how it was analysed. Even though Creswell‘s (2009) six steps of data organisation are rectilinear in nature, in this study the process was not linear. Guided by Creswell‘s first step of data organisation and preparation for analysis, the three data sets (observation, VSRI, and semi-structured interviews) were all transcribed verbatim for analysis. In total, I transcribed verbatim 10 classroom observations (see a sample in Appendix 8), three video-stimulated recall interviews (see a sample in Appendix 9) and three semi-structured individual interviews (see a sample in Appendix 11). Where participant teachers‘ code-switched or code-mixed IsiZulu and English language during lesson observation and during interviews, I transcribed in IsiZulu and translated into English for the benefit of readers to understand and make meanings of teachers and learners‘ utterances. I am IsiZulu first language speaker so I am fluent in IsiZulu language which was advantageous in the translation process. The transcription of classroom observations included teacher‘s word-to-word utterances from the beginning of each lesson till end of the lesson. Also, during demonstrations, I took screenshots of these and was included in the transcripts. Additionally, screenshots of the chalkboard writings are included in the transcripts to make sense of the classroom practices.

After the transcription process, I read through the transcribed sets of data (classroom observation, VSRI, and semi-structured interviews), as suggested by Creswell (2009). As I was reading, I made notes in the margins of the transcript (see Photographs 5-7- showing transcripts[24]). Following this process, I then read all 10 classroom observations and VSRI‘s side by side, guided by the focus of the study, and then all semi-structured interviews side by side to highlight what was similar and what was different across teachers. I followed this procedure to have a general overview of the collected data and to also think about the best ways to organise the data; a process Creswell (2007) refers to as ‘horizontalisation‘. It was this process of horizontalisation that informed the differentiated Chapters 6, 7, and 8 for data presentation and analysis and then one chapter (Chapter 9) for discussion.

Photograph 5

Sipho's classroom observation transcript


also finishing the sentence with 4 Amperes). then iyahlukana, lo 8 uhlukana kabili omunye uza then what will be the....4Amperes. 4 plus 4 is going to give us 8. Lana kuzoba ngo4 ngoba ama resistor ayalingana, they share equally. Uma ngabe engalingani, lets say this one now is 60 then definitely, ehmmm what will be the current it will be equal to ehhhhh...it is going to become smaller, its going to be (learners: 2) its going to be 2 but then ngeke isafana nale ewu 8 la. Kushuthi uma ku-2 la ngeke asafana ngeke kusaba u-8 but if lena seyishintshile uyabona ukuthi ngeke asalingana ama-current. What is happening here also this it says, uma ngabe resistor inkulu izothatha current enjani (learners: encane) encane. Lena uma ngabe izothatha 6 lena izothatha 2 ukuze kuzokwenza u-8. According to ratio, we say the greater the resistance, the smaller the (learners: current) current. Now lets compare our notes with what is happening here. Looking at this, one sithe if ama-resistor wakho are connected in parallel you are going to get a smaller resistance, the resistance is going to be smaller. And if they are in series, the resistance is going to be bigger or its going to be greater than the biggest resistor in the circuit, ok. Now lets go to ama-current, what's happening with the current here, the current we said it was 2 here, so which means the greater the resistor, we said the bigger the resistor the smaller the current. sikhuluma ngama resistor afanayo angu 30-30 angithi (learners: yes). But ngapha if you come here you see the current is no longer 2 but 4, but the resistor is the same, which means the smaller the resistor the bigger the current. Also we said the potential difference here is the same 120-120, the current here splits, bekungu-8 yahlukana yaba-4 – 4. But ngale the current is the same, the thing that splits is potential difference. So this is what is happening, when you deal with a combination of resistors (then the teacher wakes up, disciplines the learner who had been asleep for the past 10 minutes). So when you deal with ama-resistor, the combination of resistors, you first check if the resistors are parallel or are series. If they are parallel you must put in your mind that their current must be the same and then if they are parallel the thing that is going to be same is potential difference and then you deal with the calculations after that.

Now you all have this

Comment [S67]: The teacher did not complete the question but was pointing at the second resistor of the parallel circuit and came with 4 Amperes as an answer.

Comment [S68]: The teacher pointing at the first resistor with 4Amperes and the second resistor with also 4 Amperes concluding that it will give the 8 Amperes which is the toa current of the circuit....as he points at 8A

Comment [S69]: Pointing at two resistors

Comment [S70]: Changing one resistor from 30 Ohm to 60 Ohm

Comment [S71]: Looking closely at the circuit.

Comment [S72]: 8 which is the total current of the circuit.

Comment [S73]: Teacher writes the R=V/I equation and points at R and then I... the inverse proportion relationship is used here to deduce that if one is big/increases then the other will be small/decrease.

Comment [S74]: The resistor of 30 Ohms

Comment [S75]: The resistor of 60 Ohm

Comment [S76]: Teacher points at the Ohms law equation drawn on the chalkboard for this relationship.

Comment [S78]: Pointing at the total current of the previously drawn series circuit.

Comment [S77]: Pointing at the already drawn Ohm's Law equation (R=V/I)

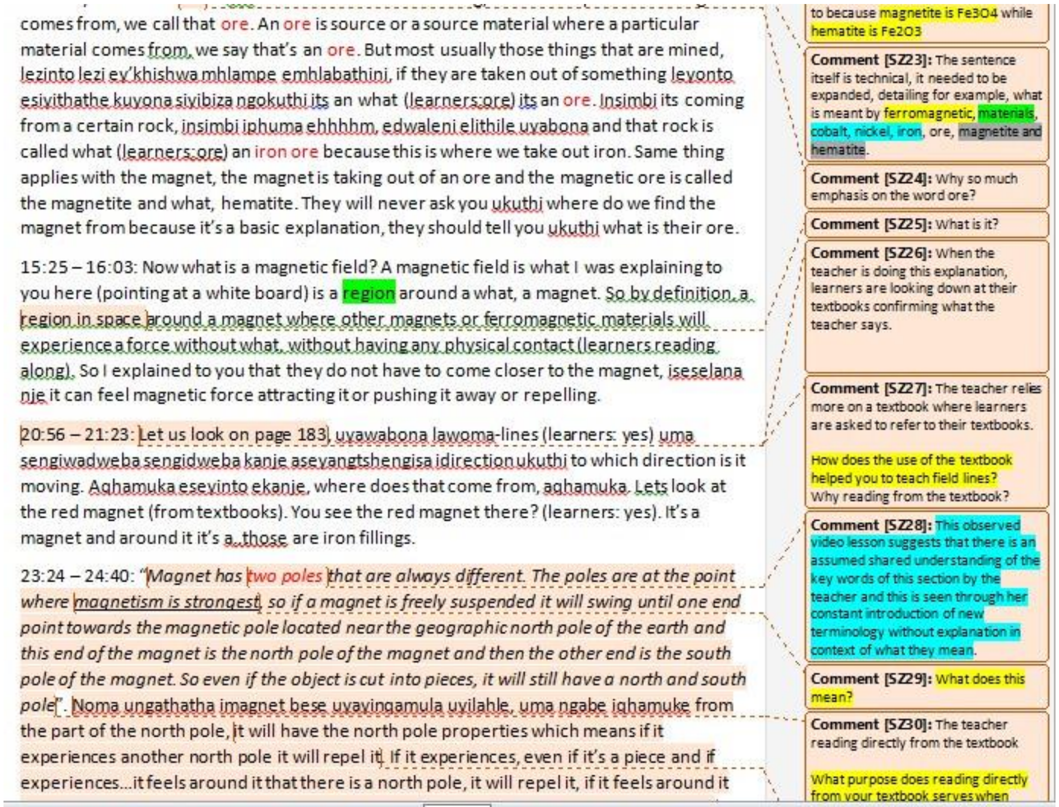
making a scientific story within lesson...

Comment [S79]: Pointing at the drawn parallel circuit on the chalkboard

[24] Appendices 8, 9, and 11 show the sample transcripts for classroom observations, video-stimulated recall interviews, and semi-structured interviews accordingly.

Photograph 6

Thando's classroom observation transcript



comes from, we call that ore. An ore is source or a source material where a particular material comes from, we say that's an ore. But most usually those things that are mined, lezinto lezi ey'khishwa mhlampe emhlabathini, if they are taken out of something leyonto esivithathe kuyona sivibiza ngokuthi its an what (learners:ore) its an ore. Insimbi its coming from a certain rock, insimbi iphuma ehhhhm, edwaleni elithile uyabona and that rock is called what (learners:ore) an iron ore because this is where we take out iron. Same thing applies with the magnet, the magnet is taking out of an ore and the magnetic ore is called the magnetite and what, hematite. They will never ask you ukuthi where do we find the magnet from because it's a basic explanation, they should tell you ukuthi what is their ore.

15:25 – 16:03: Now what is a magnetic field? A magnetic field is what I was explaining to you here (pointing at a white board) is a region around a what, a magnet. So by definition, a region in space around a magnet where other magnets or ferromagnetic materials will experience a force without what, without having any physical contact (learners reading along). So I explained to you that they do not have to come closer to the magnet, iseselana nje it can feel magnetic force attracting it or pushing it away or repelling.

20:56 – 21:23: Let us look on page 183, uyawabona lawoma-lines (learners: yes) uma sengiwadweba sengidweba kanje aseyangtshengisa idirection ukuthi to which direction is it moving. Aghamuka eseyinto ekanje, where does that come from, aghamuka. Lets look at the red magnet (from textbooks). You see the red magnet there? (learners: yes). It's a magnet and around it it's a..those are iron fillings.

23:24 – 24:40: "*Magnet has two poles that are always different. The poles are at the point where magnetism is strongest, so if a magnet is freely suspended it will swing until one end point towards the magnetic pole located near the geographic north pole of the earth and this end of the magnet is the north pole of the magnet and then the other end is the south pole of the magnet. So even if the object is cut into pieces, it will still have a north and south pole*". Noma ungathatha imagnet bese uyayingamula uyilahle, uma ngabe ighamuke from the part of the north pole, it will have the north pole properties which means if it experiences another north pole it will repel it. If it experiences, even if it's a piece and if experiences...it feels around it that there is a north pole, it will repel it, if it feels around it

to because magnetite is Fe3O4 while hematite is Fe2O3

Comment [SZ23]: The sentence itself is technical, it needed to be expanded, detailing for example, what is meant by ferromagnetic, materials, cobalt, nickel, iron, ore, magnetite and hematite.

Comment [SZ24]: Why so much emphasis on the word ore?

Comment [SZ25]: What is it?

Comment [SZ26]: When the teacher is doing this explanation, learners are looking down at their textbooks confirming what the teacher says.

Comment [SZ27]: The teacher relies more on a textbook where learners are asked to refer to their textbooks.

How does the use of the textbook helped you to teach field lines?
Why reading from the textbook?

Comment [SZ28]: This observed video lesson suggests that there is an assumed shared understanding of the key words of this section by the teacher and this is seen through her constant introduction of new terminology without explanation in context of what they mean.

Comment [SZ29]: What does this mean?

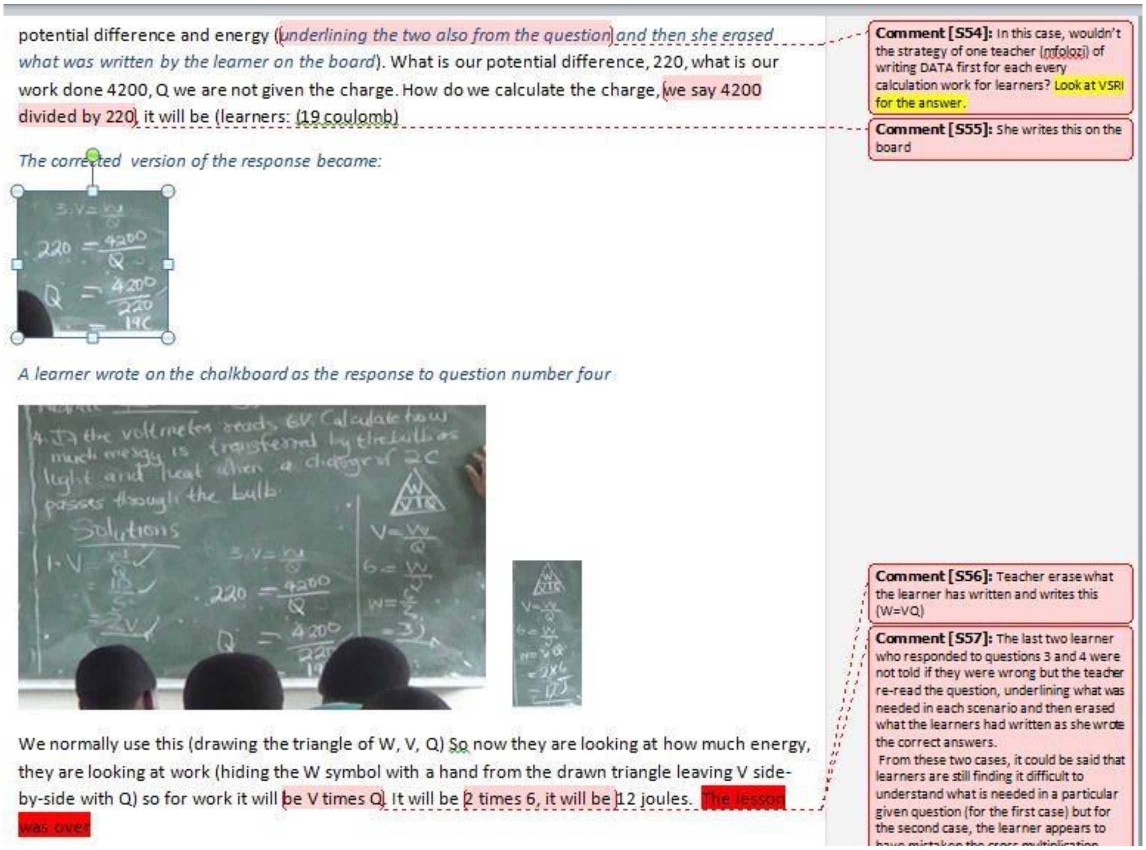
Comment [SZ30]: The teacher reading directly from the textbook

What purpose does reading directly from your textbook serves when

Moreover, I applied Creswell's third step of organising data by segmenting teachers' statements from the interviews in relation to their observed teaching practice (actual wording used during teaching). I then labelled the emerging patterns from each teacher and across teachers' lessons in relation to their pedagogical reasoning through VSRI and beliefs exposed in the semi-structured interviews (patterns to be detailed in section 4.9.2). Once the patterns were noted, I then coded these patterns, and grouped them into themes (see Table 13). Initial themes were identified and were refined in relation to the focus and research question of the study. (Refer to Photographs 8-10 showing the selected part in data categorisation and development for analysis.)

Photograph 7

Amanda's classroom observation transcript



potential difference and energy (*underlining the two also from the question and then she erased what was written by the learner on the board*). What is our potential difference, 220, what is our work done 4200, Q we are not given the charge. How do we calculate the charge, we say 4200 divided by 220, it will be (learners: (19 coulomb)

The corrected version of the response became:

A learner wrote on the chalkboard as the response to question number four

We normally use this (drawing the triangle of W, V, Q) So now they are looking at how much energy, they are looking at work (hiding the W symbol with a hand from the drawn triangle leaving V side-by-side with Q) so for work it will be V times Q. It will be 2 times 6, it will be 12 joules. The lesson was over

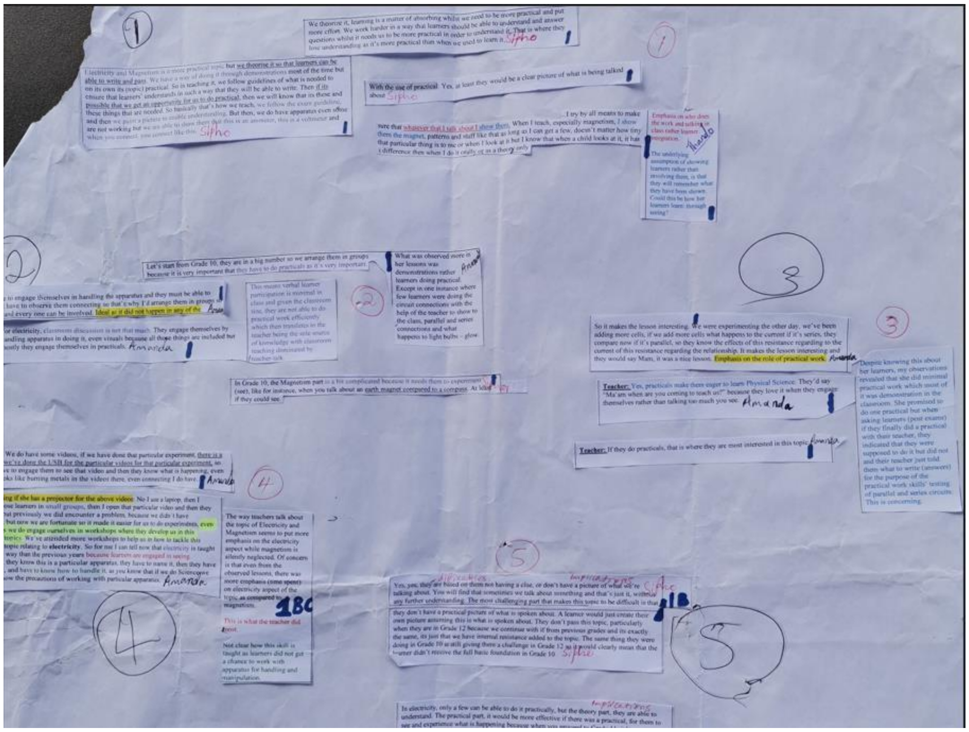
Comment [S54]: In this case, wouldn't the strategy of one teacher (mfolozi) of writing DATA first for each every calculation work for learners? Look at VSRI for the answer.

Comment [S55]: She writes this on the board

Comment [S56]: Teacher erase what the learner has written and writes this (W=VQ)

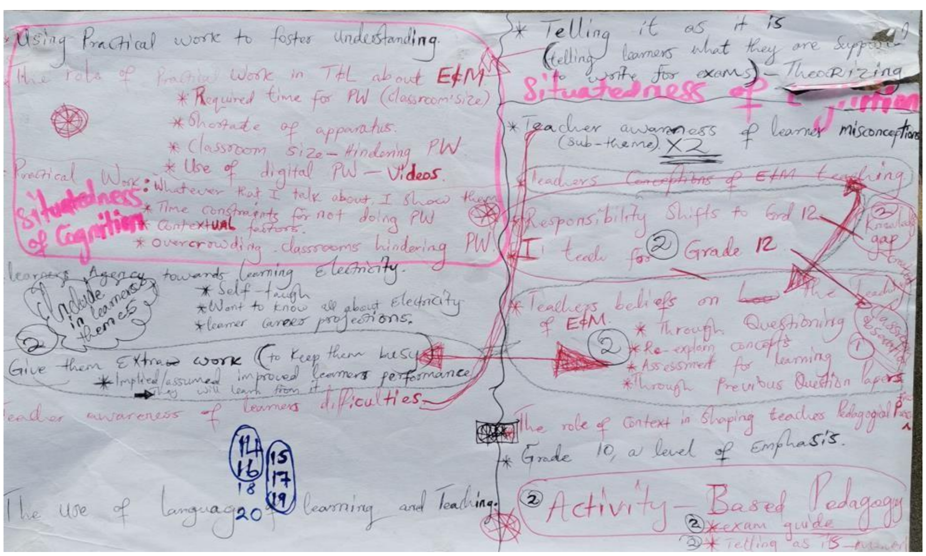
Comment [S57]: The last two learner who responded to questions 3 and 4 were not told if they were wrong but the teacher re-read the question, underlining what was needed in each scenario and then erased what the learners had written as she wrote the correct answers.
From these two cases, it could be said that learners are still finding it difficult to understand what is needed in a particular given question (for the first case) but for the second case, the learner appears to

According to Creswell (2009), the fifth step involves the advancement of themes' description for better representation of data in the discussion of the findings. In this step, I purposefully selected some parts from the data and pasted them on the chart under each theme (refer to Photographs 8 and 10 and Appendix 12) to describe and support the themes emerging from the data of this study. Pasting notes under each theme allowed me to identify the emergence and divergence of data within teachers and across teachers, in relation to the aim of the study. (See Table 8 detailing the emerged themes and how they were identified from data). The last step, according to Creswell (2009), includes the creation of meanings to the raw data. For this study, I also noted that raw data was meaningless until it was made to talk to the focus of the study through interpretations. The meaning-making process took into consideration Mavhunga's (2012) tsPCK framework and Scott et al.'s (2011) pedagogical link-making. PLM and tsPCK frameworks afforded me an opportunity to make sense of the data, especially the classroom observation data and VSRI data, while critical discourse analysis assisted with organising the semi-structured interview data.



Photograph 8

Initial Data Categorization

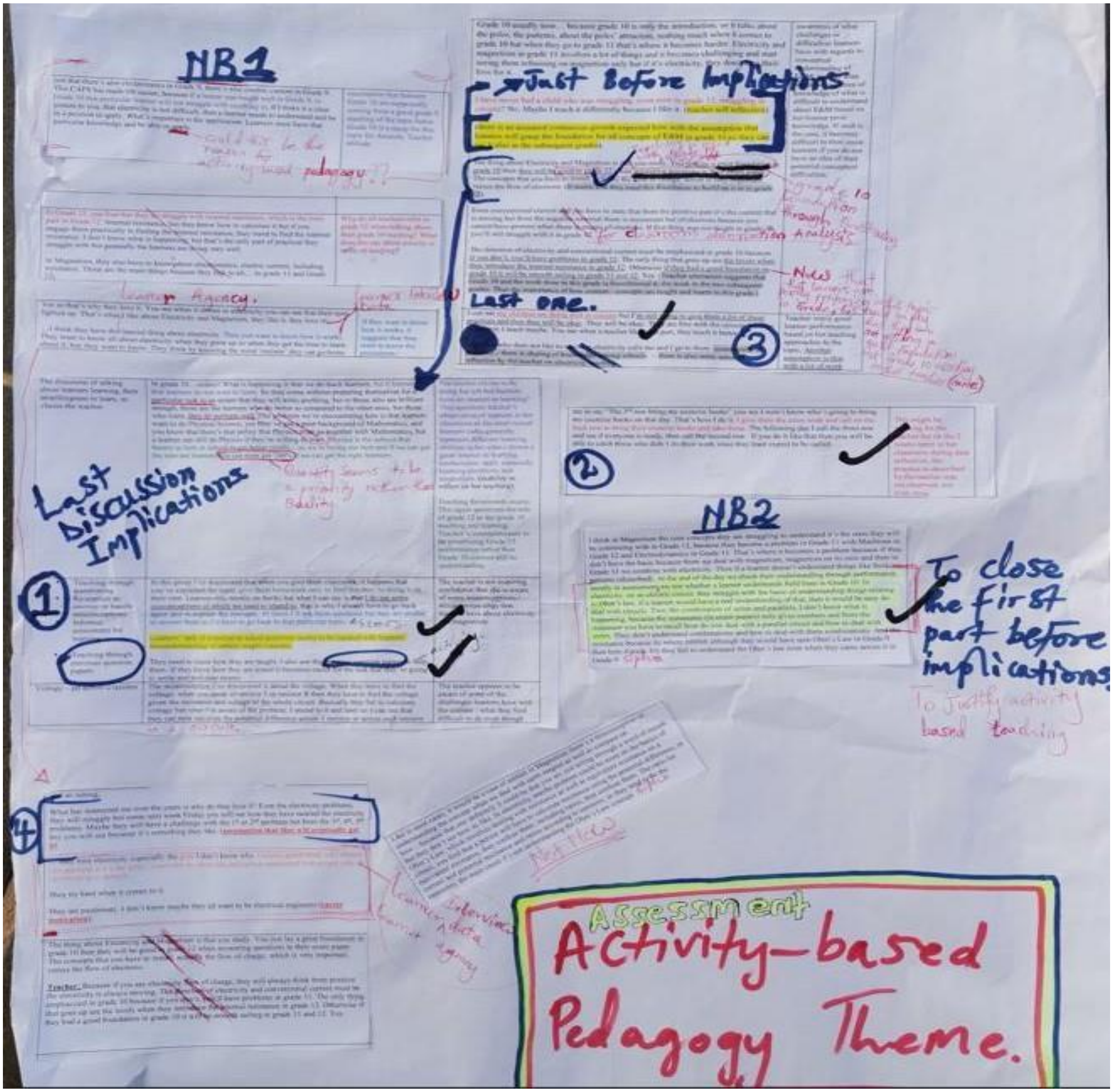


Photograph 9

Initial Theme identification

Photograph 10

Sample of a theme organisation



4.9.2. Data analysis

In qualitative research, the analysis of data involves the organisation, accounting for and explanation of qualitative data (Cohen et al., 2007). The data for this study was analysed through an inductive process where classroom observation data sets, VSRI data sets, and semi-structured interviews data sets were categorised to explore emerging patterns and relationships within teacher practices and across teachers. Firstly, I focussed on the thick descriptions of each data set for internal patterns and relationships for each teacher. Secondly, I examined and analysed emerging patterns and relationships across teachers. To demonstrate this analysis, I show the classroom observation analysis followed by VSRI analysis, and lastly, the semi-structured interview data analysis is also presented. Given the purpose of this study, the classroom observation data was analysed first to explore teachers‘ pedagogical approaches. In this analysis process, dominant pedagogical approaches for Electricity topic teaching emerged. The dominant approaches were reasoned through VSRI data and supplemented by semi-structured interviews data. The following section presents classroom observation data analysis strategy.

4.9.2.1. Classroom observation data analysis

The analysis of classroom observation data was done with Mavhunga‘s (2012) theory of topic specific pedagogical content knowledge as the lens, Scott et al.‘s (2011) PLM concept, Mortimer and Scott‘s (2003) communicative approaches and Initiation-Response-Evaluation/Feedback (IRE/F). The theoretical and conceptual frameworks used for the analysis were explained in Chapter 3 and comprehensive analysis of each lesson through these frameworks is detailed in chapters 6 to 8 of the thesis. For the processes of classroom observation data analysis, I watched the video-recorded lessons alongside the transcription of each recorded lesson per teacher. The recorded lessons were re-watched for several times. After confirmation of the contents of the recorded lesson and each lesson transcript, I re-read the transcripts to identify all observable pedagogical approaches per lesson. Notes on the margins of the observation transcripts were made during the re-reading process (see Photographs 5-7). Comments about observable focus of teacher‘s teaching, teacher‘s communicative approaches including patterns of discourse as presented in Tables 10 and 11, were the focus on the notes in the margins of each observation transcript. Key words and phrases were identified during this process. The notes on the margins helped in the process of teaching episodes‘ identification from each lesson; see Table 15 for a guide on episode identification in section 5.3. Thereafter, each lesson was organised according to the identifiable episodes which are summarised in Table 14 and analysed in chapters 6-8 per teacher, per lesson.

Furthermore, the content of each episode was coded using PLM and tsPCK. Communicative Approaches and Initiation-Response-Evaluation/Feedback (IRE/F) were also important to understand classroom communication and patterns of teachers‘ discourses during the coding process. The combination of PLM, tsPCK, Communicative Approaches, and IRE/F helped to engage with the data in-depth, because each frame presented a nuanced process to ensure nothing was missed. However, interesting patterns that emerging from data which were outside the boundaries of the abovementioned combination of concepts, were also considered and analysed. Therefore, a comprehensive analytical framework to organise and analyse data is developed in Chapter 5. The analytical framework was used to search for general statements about relationships among themes of data. Tables 8-12 demonstrates how each lesson contents was coded for Amanda, see Appendix 12 for the explanation of codes used in Tables 8-12 and for the coded Sipho and Thando‘s lessons in the same appendix.

Table 8

Amanda's Lessons coded through tsPCK

TsPCK components	**Features/characteristics**	**Codes**	**Frequency**			
			L1	L2	L3	**TOTAL**
Learner Prior Knowledge (LPK)	Addressing misconceptions	LPK - Mis	-	-	1	**1**
	Pre-requisite knowledge	LPK - Pre	1	2	3	**6**
Curricular saliency (CSA)	Knowledge in curriculum	CSA - KC	3	2	-	**5**
	Emphasis	CSA - Em	2	3	1	**6**
	Reflecting on pre-requisite knowledge	CSA - RPre	2	-	-	**2**
Representations (REP)	Sub-Microscopic	REP - 1	-	-	-	**-**
	Macroscopic	REP - 2	7	6	-	**13**
	Symbolic	REP - 3	11	14	7	**32**
What is difficult to teach or learn (WDT/L)	Difficult concepts/processes for teaching & learning	WDT/L - DTL	2	2	-	**4**
Conceptual teaching strategies (CTS)	Confirmation / confrontation of LPK	CLPK	7	6	-	**13**

Table 9

Amanda's Lessons coded through PLM

Pedagogical Link-Making Approaches	Features / characteristics	Sub-concepts	Codes	Frequency			
				L1	L2	L3	TOTAL
To support knowledge building	Making links between everyday and scientific ways of explaining	Integration	LES – 1	1	-	-	**1**
		Differentiation	LES – 2	3	-	-	**3**
	making links between scientific explanations and real world phenomena	Concrete phenomena	SERW – 1	-	1	-	**1**
		Complex phenomena	SERW – 2	1	7	-	**8**
	Moving between different scales and levels of explanation	Sub-micro - macroscopic	SLE – MiMa	-	1	-	**1**
		Sub-microscopic to symbolic	SLE - MiSy	-	-	-	**-**
		Macro to sub-microscopic	SLE – MaMi	2	2	-	**4**
		Macroscopic to symbolic	SLE – MaSy	3	-	-	**3**
		Symbolic to macroscopic	SLE – SyMa	-	-	-	**-**
		Symbolic to sub-microscopic	SLE – SyMi	-	-	-	**-**
	Links between scientific concepts	Integration	SCT – 1	9	9	2	**20**
		Differentiation	SCT - 2	4	3	-	**7**
To promote continuity	Continuity to develop the scientific story	Macro scale	CSS – 1	6	-	-	**6**
		Meso scale	CSS – 2	7	1	1	**9**
		Micro scale	CSS – 3	1	1	1	**3**

I used Mortimer and Scott‘s (2003) communicative approaches to make sense of teacher‘s interaction processes with learners, and with content in communicating the Electricity topic ideas. Therefore, the communicative approaches helped this study to uncover "…different pedagogical stances taken by the teacher as they interact with a class of students" (Scott et al., 2011, p. 19). This means that teachers could open or limit classroom interactions during Electricity topic lessons and this study was concerned with the nature of interactions promoted by each teacher in each lesson. Mortimer and Scott (2003) characterised communicative approaches into four categories. Firstly, interactive, and non-interactive talk during teaching, where the teachers talk is interactive when involving the participation of the teacher and learners and non-interactive if only involving the participation of the teacher. Secondly, the dialogic and/or authoritative classroom talk, where dialogic communication involves the teacher and learners paying attention to more than one point of view, more than one voice is heard and there is exploration or interanimation of ideas, while authoritative communication involves focusing on one point of view, only one voice is heard and there is no exploration of different ideas (Scott et al., 2011). Table 10 depicts the four categories of communicative as interactive/dialogic; non-interactive/dialogic; interactive/authoritative; and non-interactive/authoritative approaches. After this is Table 11 to demonstrate the coding of data through communicative approaches.

Table 10

***Four categories of communicative approaches used in classrooms* (as adapted from Mortimer & Scott, 2003; Scott et al., 2011)**

Communicative Approach	Description
Interactive/dialogic	The teacher seeks to elicit and explore students‘ ideas about a particular issue.
Interactive/authoritative	The teacher leads students through a sequence of instructional questions and answers.
Non-interactive/dialogic	The teacher pulls together and presents students‘ ideas and also draws attention to the differences between everyday and scientific points of view.
Non-interactive/authoritative	The teacher presents a specific point of view.

Table 11

Amanda's Lessons coded through Communicative Approaches

Features/characteristics	**Codes**	**Frequency**			
		L1	**L2**	**L3**	**TOTAL**
Interactive/dialogic	Int-Di	1	-	-	**1**
Interactive/authoritative	Int-Au	3	3	3	**9**
Non-interactive/dialogic	Non-Di	-	-	-	**-**
Non-interactive/authoritative	Non-Au	1	1	4	**6**
Evaluative/authoritative	Eval-Au	2	-	-	**2**
Feedback/authoritative	Fb-Au	-	-	-	**-**

Linked to the communicative approaches is Mortimer and Scott's (2003) patterns of discourse which focuses on the simple, but distinctive patterns of interaction that emerged between teachers and learners during ongoing classroom teaching. I was interested with the patterns of interaction that developed in the discourse as teachers and learners took turns in classroom talk. These patterns usually displayed themselves in patterns of three with utterances from the teacher-learner-teacher hence Mortimer and Scott (2003) refer to it as a triadic I-R-E interaction. I-R-E stands for initiation, often by the teacher, then response by learners and evaluation by the teacher. Sometimes the teacher gives feedback instead of evaluation and it becomes I-R-F. Table 12 shows the coding for the patterns of discourse.

Table 12

Amanda's Lessons coded through Patterns of Discourse

Features/characteristics	**Codes**	**Frequency**			
		L1	**L2**	**L3**	**TOTAL**
Initiation – Response – Feedback	IRF	6	3	1	**10**
Initiation – Response – Evaluation	IRE	2	4	1	**7**
Initiation – Response	IR	4	2	-	**6**

The frequency of coded classroom practices was categorised into patterns searching for emerging patterns across teachers‘ classroom data. I then reviewed the identified patterns into themes (shown in Table 13), defined and refined themes and, lastly, produced a report (write-up) (Braun & Clarke, 2006). The emergent themes from classroom observation were developed alongside the analysis of semi-structured interviews and VSRI, and these comprehensive themes (discussed in Chapter 9) were used to address the research problem under investigation (Maguire & Delahunt, 2017).

Table 13

Categorisation of data into themes

Theme	Sub-themes	Theme Identification (examples from excerpts)
Teachers pedagogical approaches to Electricity topic	i. *The symbolic nature of Electricity topic: Using different modes of representations and analogies to teach Electricity* ii. *Importance of supporting Electricity topic knowledge building* iii. *The role of practical work in the development of learners' scientific knowledge building*	**Amanda**: We represent these **components** using symbols. So there are symbols that we use in science so that we know what we are talking about. When you are talking about a cell, this is a positive terminal and this is a negative terminal. And then when you got more than two cells, it is no longer a cell but it is a …battery, this is a symbol which shows a battery. Then we have a voltmeter, how do we represent a voltmeter? This is symbol V, a voltmeter…A closed switch, this is a symbol for a switch which we said it is closed… Let me make a diagram which will illustrate a cell which is said it is connected and is complete (lesson 1, episode 3) **Thando**: *I try by all means to make sure that whatever that I talk about, I show them… as long as I can get a few (things to show), doesn't matter how tiny that particular thing is to me or when I look at it but I know that when a child looks at it, it has a difference then when I do it orally or as a theory only*. **Amanda:** So here with me I have a circuit board, this is my circuit board. And here I got some components which are found in a circuit… I'm going to show you the components first so that it will be easier. These are the components, the light bulb… We do have connecting wires, and then we do have a cell holder and then we know this is a? [**Learners chorusing**: _A cell']. This is a cell, when we've got two or more cells together they form a battery…this is an ammeter, an ammeter measures current... (lesson 1, episode 2) **Amanda**: *Let's start from Grade 10, they are in a big number so we arrange them in groups because it is very important that they have to do practicals as it's very important*. **Sipho**: *You will find that sometimes we talk about something and that's just it,*

		without any further understanding. The most challenging part that makes this topic to be difficult is that they don't have a practical picture of what is spoken about. **Amanda**: *Practical make them eager to learn physical science* **Sipho**: *We have a way of doing it through demonstrations most of the time but on its own its (Electricity) practical.* **Sipho**: *Through demonstration, at least there would be a clear picture of what is being talked about.* **Amanda**: *For electricity, classroom discussion is not that much. They engage themselves by handling apparatus in doing it, even visuals because all those things are included, but mostly they engage themselves in practicals.*
Teaching Electricity topic and concepts for teachers' own learning.	i. Closed evaluative and feedback authoritative communicative approaches. ii. Initiation-Response-Confirmatory (IRC) approach	**Amanda**: okay let me revise this again, let's check here again *(pointing to the last diagram drew)* you will be given any scenario it can be a given diagram, let's say you are given and then you are required to know, first of all the type of diagram, if you look at this diagram, it shows that the resistors which are connected in series so they follow one another, alright so now you need to find the total resistance of the resistors connected in series. If they are in series what do we do? We said if they are in series we add all the resistance of the resistors. We add all the resistance of the resistors, so here in this second diagram how many resistors do we have? 1, 2, 3 and then we said the formula for calculating resistance of resistors in series we said R_s so Rs means the total resistance of the resistors in series. So now we use the formula $R_1 + R_2$ if they are two, if they are three we said $+ R_3$ and if they are 4 then we can add $+ R_4$. Then we calculate we get this answer, so this answer is for the total resistance of the resistors connected in series. Now the other question says calculate the voltage, now in this circuit diagram you were given the total voltage of this circuit as 9v, do you hear me? It was 9V. (lesson 3, episode 2) **Amanda:** then we go to number B, Calculate the equivalent resistance for this circuit, leave your answers as a fraction, now how do we calculate the equivalent resistance, let's use the formula so we've got (*teacher writes the equation on the*

		board) $1/R_P = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 = 1/1 + 1/2 + 1/4 + 1/8$ and then we look for our lowest common denominator okay? What was our common denominator? [**Learners:** 6] what about 8? [**Learners:** yes] the nearest one is 8, the lowest common multiple is 8, okay 1 into 8? [**Learners:** 8] 2 into 8? [**Learners:** 4] 4, here? (*pointing at 4*) [**Learners:** 2] here? (*pointing at 8*) [**Learners:** 1] right say 8 and 2, it is 10, 15/8 we get 15/8. We do not want $1/R_P$ but we want R_P so we said =8/15, then you come up with the answer what did you obtain? [**Learners:** 0.5] grade 10 what was the correct answer? [**Learners:** it said in fraction] Yes in fraction, very good so it means we need the answer like this but if we make it into the first decimal comma it is 0.53 and then there is it, how many obtained it correct, how many obtained it correct? How many? (*no response*) and then we are done now, do corrections, do corrections and then I'm going to give you another task. (lesson 3, episode 3)
Factors that shape rural teachers' pedagogical approaches	i. Rurality and practical work at loggerheads ii. Teaching for assessment: Assessment-driven pedagogy	**Thando**: *So as much as the time and space hinder us from doing a lot of practical work that we could do if the cases were different, because one of the things that disturb us is that our children are collected from afar in remote areas to this school by buses and when the school is over for the day, they have to be taken back home by buses so it is not easy to have extra classes with those learners. So practical work always needs an extra class because you still need to finish the curriculum.* **Thando**: *But since there are 85 learners, if I can involve each and every one then it will be havoc, so let me just make them remember what they see so I'll go to the _remember route' because the involvement part, ooooooh.* **Amanda**: *So with this large group it takes time because you have to attend this particular group, then later you will run short of apparatus.* **Sipho**: *We do have (apparatus), but they're old. They are the older model and they are not so user friendly.* **Sipho VSRI:** *We theorise it, learning is a matter of absorbing whilst we need to be more practical and put more effort. We work harder in a way that learners should be able to understand and answer questions whilst it needs us to be more practical in order to understand it. That is where they lose understanding as it's*

		more practical. **Sipho***: You end up saying what they'*re supposed to write (exams), meaning you're telling it as it is, for them to understand theory, but there wouldn't be a clear understanding.* **Amanda VSRI**: *There is a shortage of textbooks'*; *_learners need the chalkboard summary'*; *_if the advisers (department officials) come, they need the summary of the days…they want to see where and when did you do this*

4.9.2.2. VSRI and Semi-structured interviews data analysis

The VSRI and semi-structured interviews were analysed after classroom observation data. As already explained through Creswell‗s horizontalisation, both interview‗s data sets were categorised through making notes on the interview transcripts as shown in Photographs 5-8 below. The analysis process was guided by Fairclough‗s Critical Discourse Analysis (CDA), because I wanted to critically analyse teacher‗s ‗praxis‗ – critical reflection to their teaching approaches. Fairclough (1993) foregrounds the dialectical relationship between society and language when arguing for communicative events as being instances of language use, analysed as text, discursive practice, and social practice. The following analysis focussed on the linguistic features of the text (what is said by teachers), including lexicalisation, grammar, cohesion, and text structure; the processes related to the production and consumption of the text, including the ―force‖ of utterances, coherence, intertextuality, and interdiscursivity; and lastly, the institutional and organisational circumstances of the discursive event and the constitutive effects of discourse. The above was done in order to move beyond ‗what‗ when analysing a text and strive for the understanding of ‗how‗ and ‗why‗ behind the oral, thought, and transcribed text as argued by Fairclough (1995).

The analysis of VSRI focussed on how teachers talk about their pedagogical practices, what kinds of words do they use to talk about their teaching. The communicative approaches (Table 11) address classroom discourses, hence CDA for teachers‗ pedagogical reasoning. Similarly, for semi-structured individual interviews, the selection of words used by teachers to talk about their background was of interest. Considering the above discussion, CDA was relevant for this study because it revealed teacher‗s beliefs and experiences of Electricity topic teaching and physical science teaching in general which was explained through language and represented teachers pedagogical reasoning while also exposing factors that shape teachers‗ pedagogical approaches.

Furthermore, tsPCK (LPK, WDT/L, CTS) and PLM‗s continuity links and to some extent knowledge building link-making promotes the social interactions when teaching science. Communicative approaches helped to understand these classroom interactions while CDA has further exposed the hidden meanings of teacher text/speech (language) during the lessons and interviews sessions. So how teachers talked about the teaching and learning of Electricity topic was crucial for critical interpretive study. Therefore, both VSRI and semi-structured interviews were interested with how teachers represented Electricity topic including how they spoke about learner prior knowledge, representations to represent concepts, what is difficult to teach/learn about electricity concepts, availability of resources and how it shapes their classroom practices, content in curriculum and time frames for Electricity topic teaching, among other aspects reflected on by teachers. These aspects helped to focus interviews�as information to observable classroom practices. Thus, semi-structured interviews and VSRI data were sampled to focus on teachers comments in relation to major codes from classroom observation analysis. This process was informed by frequency of codes in Appendix 12.

4.10. Unit of analysis

Unit of analysis is understood to be the object that is to be described in terms of the research variables (Dowling & Brown, 2010). Accordingly, the unit of analysis was neither the rural teachers involved in this study nor the learners observed in this study but rather the pedagogical approaches—teachers‘ classroom practices which included their consideration of learners‘ prior knowledge and what is difficult to teach and/or learn during their teaching; use of and moving between different levels of representations; teachers‘ sequencing of concepts in curricular, including teacher emphasis during explanations; and the teachers‘ link-making for knowledge building and content continuity. The unit of analysis is detailed in Figure 9 (Chapter 5).

4.11. Ensuring the quality of the study's trustworthiness

In this section, I present processes followed to maximize trustworthiness of the data and findings of this study. Trustworthiness refers to the quality of both research findings and gathered data and is said to have four components or strategies being; credibility, transferability, dependability and confirmability (Babbie & Mouton, 2007). Each strategy is briefly presented below due to their discrete and collective importance in conducting research.

4.11.1 Credibility

McMillan (2012) defines credibility "as the extent to which data, data analysis, and conclusions are accurate and trustworthy" (p. 302). Creswell (2009) suggests some procedures to enhance credibility in qualitative studies. I spent a reasonable enough time with teachers in their setting as McMillan (2012) suggests prolonged engagements. After data generation process, I sent teachers classroom observation videos and interview transcripts for purposes of member checking. After this process, I went back to the teachers who provided me with the information to verify my interpretations of their responses and actions. Also, different sources and methods of data generation were used for triangulation of results. Furthermore, negative case analysis was done in the analysis and discussion chapters to represent and reflect on discrepant information to enhance the credibility as argued by McMillan (2012). Additionally, I used thick description when analysing findings of this study. Also, my findings including conclusions were given to some colleagues and supervisor to review whether results follow from the data. Lastly, I reflected on my positionality in section 1.1 and how it could influence my expectations, interpretations, and conclusions, hence reflected upon to enhance credibility of the findings of this study.

4.11.2 Transferability

Babbie and Mouton (2007) refers to transferability as an extent to which the findings of the study can be applied in other contexts or with other respondents. McMillan (2012) identifies thick description of the site, participants, and procedures used to generate data as strategies for ensuring transferability. Accordingly, I have provided a detailed account of the rural school settings in this chapter, teachers, sample size and strategy, and interviews and classroom observations. Considering the complexities of rural areas and the difficulty of the Electricity topic, this study does not claim that findings or knowledge gained from one context will necessarily be relevant to other contexts or for the same context in another time frame (Babbie & Mouton, 2007), but the findings will give a picture of what might be happening in some Grade 10 physical science classrooms, especially those located in South African rural areas.

4.11.3 Dependability

Dependability is linked to the consistency of research findings if the similar study were to be repeated but this will be influenced by the context to which the study was to be repeated, the methodology used to collect and analyse data (Babbie & Mouton, 2007). As such, my research supervisor acted as an inquiry auditor by examining the product, the data, findings, interpretations, and recommendations, and attests that it is supported by data and internally coherent so that they may be accepted. This was done to ensure the dependability of the findings and conclusions of this study. Furthermore, to allow the reader to assess the extent to which appropriate research practices were followed, I provided thick description of the methodological processes followed from the conceptualisation of the study until end.

4.11.4 Confirmability

To confirm my interpretations and conclusions on research data, I made both raw data and interpreted data available to my supervisor to confirm the findings in accordance to raw data. Confirmability, according to Babbie and Mouton (2007), is the degree to which the findings are the product of the focus of the inquiry and not of the biases of the researcher. As such, conclusions, interpretations, and recommendations of this study were traced to their sources by my supervisor to ensure confirmability of findings and my interpretations.

4.12. Chapter summary

This chapter discussed in detail and justified the research process and methods used in generating, organising and then analysing the qualitative data. A qualitative research approach allows the researcher to obtain an in-depth exploration of a certain phenomenon to gain an understanding of that situation. Video-stimulated recall interviews, semi-structured interviews, and classroom observations were used as tools to generate data because they allowed in-depth engagement with the research questions of the study (Creswell, 2012). Additionally, this chapter outlined important aspects regarding the different methods involved in conducting and analysing qualitative data. Lastly, the essentiality of ethics and that which it encompasses were also considered (Cohen et al, 2007).

CHAPTER 5

The emergence of an analytical language

5.1. Introduction

In Chapter 4, I presented and justified the methodological choices and decisions for this study. Chapter 5 presents and discusses the analytical language of this study in relation to the frameworks as discussed in Chapter 3. A detailed explanation and demonstration of how data were coded and analysed, including the organisational language that was used in the analysis of this study, are presented in this chapter. I further describe how classroom observation data, video-stimulated recall interviews, and semi-structured interviews were analysed in relation to the discussed theoretical and conceptual frameworks. Since classroom observations were analysed according to teaching episodes, I begin this chapter by explaining what an episode is and how I identified a teaching episode from the classroom observation data.

5.2. Teaching episodes

The observed classroom lessons were analysed comprehensively and identified instances where teachers demonstrated teaching approaches, which are labelled teaching episodes. A teaching episode is a unit of time within which teachers and learners are trying to achieve a certain educational objective(s) and are engaged in the same teaching and/or learning style (Chatoupis, 2016). Each teaching episode represents a unique teaching style and reinforces the specific educational objectives of a subject matter. Moreover, Chatoupis (2016) argues that there may be more than one set of objectives in a lesson, thus each lesson may require a series of episodes to accomplish the lesson‘s overall intent. Similarly, in this study, each observed lesson had a series of teaching episodes building towards the lesson objective(s). The teaching episodes had different time frames, some lasted longer and others lasted only for few minutes, thus their time frames differed, depending on the focus of each episode.

Moreover, to capture each teaching episode of the lessons, the video-recorded classroom observation data were analysed through three approaches: in-depth analysis of explicit tsPCK to support knowledge building; the descriptive approach; and the constant comparative methods as suggested by Park and Chen (2012). Regarding the in-depth analysis of explicit tsPCK to support knowledge building, I identified teaching segments from the video-recorded classroom lessons that revealed the use of tsPCK to support knowledge building in accordance with my operational definition of teaching episodes. For this purpose, the study adopted Park and Chen‘s (2012) understanding of a PCK episode as an "integration of two or more components" (p. 928). Similarly, a teaching episode for this study meant the integration and interaction of various tsPCK to support knowledge building components as determined in Figure 5 in Chapter 3. Therefore, each identified episode needed to demonstrate two or more networked components of tsPCK to support knowledge building. In essence, each teaching episode was identified[25] by having a *teaching focus* (teaching purpose and content taught); clear *communicative approach*; and *teacher action* (patterns of discourse and teacher interventions and learner tasks). Table 14 presents the number of analysed teaching episodes found in each classroom lesson.

Table 14

A summary of teaching episodes from the observed lessons

Teacher	Lesson	No. of Episodes	Total Teaching Episodes
Amanda	Lesson 1	5	
	Lesson 2	3	**11**
	Lesson 3	3	
Sipho	Lesson 1	3	
	Lesson 2	2	**6**
	Lesson 3	1	
Thando	Lesson 1	4	
	Lesson 2	4	**12**
	Lesson 3	3	
	Lesson 4	1	

[25] Refer to Table 11 for a detailed guide for teaching episode identification.

5.3. Teaching as a dialogic process: Episode identification

Informed by the purpose of this study and the frameworks that were outlined in Chapter 3, I adopted Mortimer and Scott‵s (2003) tool for analysing and planning science teaching interactions (aspect of analysis). This tool has been modified to explicitly reflect Scott et al.‵s (2011) PLM and Mavhunga‵s (2012) tsPCK. The tool in Table 15 focuses on the teacher‵s role to make the scientific story available as well as supporting the learners‵ process of making sense of the teacher‵s story and developing skills to construct their scientific stories (Mortimer & Scott, 2003). After teaching episodes were identified, the contents of each teaching episode were coded for further analysis. The code identification and coding process is discussed in section 5.4.

5.4. Scientific Practices' codes and coding process

The observed classroom lessons exposed several scientific practices. According to their nature and purpose, these were categorised into four practices:

1. Scientific communication
2. Conceptual teaching strategies
3. Scientific story development
4. Evaluating scientific validity practices

5.4.1 Scientific communication

Some of these practices include: explaining scientifically, defining scientifically, initiating and/or sustaining scientific classroom talk, moving between worlds, reading scientifically, and writing scientifically. These are practices that define the science discourse, and expose scientific ways of doing and talking as practiced in a science community of practice. These practices are crucial in fostering science classroom talk and developing scientific ideas to support learners‵ understanding of the topic and concepts.

Table 15

Guide for teaching episode identification

Focus of topic teaching	Teaching purpose (conceptual teaching strategy)	Opening up the lesson objective
		Exploring and working on learners' views (working with learner prior knowledge - LPK)
		Introducing and developing the scientific story (link to promote continuity)
		Working with what is difficult to teach and/or learn about Electricity topic (WDT/L)
		Working with Big Ideas of Electricity topic and emphasis on important content knowledge (CSA)
	Content taught and learnt *(topic-specific level)*	Scientific story being taught (CTS) - Making links between everyday and scientific ways of explaining (integrate or differentiate) (working with learners' prior knowledge - LPK) - Making links between scientific concepts and their sequencing - Making links between scientific explanations and real-world phenomena - Making links between modes of representations (REP) - Moving between different scales and levels of explanation - Analogical link making - Making pedagogical links on what is difficult about the concepts taught
Approach	Communicative approach	Dialogic $\rightarrow$ authoritative talk Interactive $\rightarrow$ non-interactive talk
Action	Patterns of discourse	I - Initiation (nature and type of questioning by the teacher)
		R – Response (by teachers and learners[26])
		E – Evaluation[27] (by the teacher) / F – Feedback by the teacher (nature of feedback)

5.4.2 Conceptual teaching strategies

These are practices that characterise teacher facilitation of scientific ideas for effective meaning-making. Some of these practices include: modeling and scaffolding, using multiple approaches, coaching and guiding, fading, exemplifying, experimenting, and communicative approaches.

5.4.3 Scientific story development

These are practices that dealt with teachers' attempts to link concepts and knowledge skills from within and across lessons using the macro, meso, and micro scales. In addition practices

[26] This was done more regularly by teachers than learners in this study, as evidenced in Chapters 6-8
[27] Instead of making an evaluation of learner response, the teacher could also give the learner feedback or elaborate on the learner's answer, a practice also observed in this study

included: summarising on the board, summing up, reiterating, proceduralising, and monitoring solutions.

5.4.4 Evaluating scientific validity practices

These practices served as the authorising practices as they focused on judgments about what is scientifically legitimate. Some of these practices include: critiquing, providing justification, and critiquing solution. This practice was limitedly observed in this study. The abovementioned scientific practices are represented in following Table 16.

Table 16

The coding of classroom practices

Identification of Scientific Practices (SP)	**SP in use**	**Code**	**Code identification rule / examples from transcript**
Scientific Communication	Explaining scientifically	SC-ES	When _what' is used in a question by the teacher. Or when the intonation used by the teacher indicates a call for further explanation of concepts. This include emphasis on explaining processes, terms, etc (CSA). Also, the use of the phrase/sentence: _anything else'. **COMMENTS**: SC-ES could also be a call for someone to shed more light on what has been said (LPK). For example, **—**What do you mean by …‖ SC-ES does not necessarily need to start in the form of a question. This could be used to address difficult concepts to teach and learn (WDT/L). It could also be the explanation of a particular concept or an explanation of another learner's reasoning (LPK) or solution to a scientific problem. It could also be the link-making between scientific explanations and real-world phenomena.
	Defining scientifically	SP-DS	When particular attention is paid to the scientific register (CSA), discourse and classroom language issues, including the explicit and implicit explanation of both scientific concepts and everyday concepts used ***in*** and/or ***as*** science discourse. The above also includes the explicit links made between everyday and scientific ways of explaining, integration and differentiation of ideas. The nature of explanations was analysed as being surface or deep explanations based on what has been said, what the curricular requires and what science knows (through scientific texts) including the knowledge of Big Ideas in Electricity topic (CSA).

	Initiating and/or sustaining scientific classroom talk	SP-SCT	When there is initiation of classroom talk either by the teacher or a learner(s). This initiation can come in a form of a question, explanation, reading of text, etc. After the initiation, processes such as response, feedback and/or evaluation by the teacher and/or learners would follow. It is possible for a teacher to initiate a classroom talk, respond to their initiation and ultimately evaluate their response, as was seen in some episodes of the observed classroom practices. Another aspect of this scientific practice in use includes the nature of classroom talk—whether the classroom talk is dialogic or authoritative, whether it is interactive or non-interactive, and any other approaches that were observed during classroom practice.
	Moving between worlds	SP-MBW	When the teacher moves between the scientific world and the real world. In Scott et al.'s (2011) terms, when there is a movement between scientific explanations and real world phenomena; movement between everyday ways of explaining and scientific ways of explaining. SP-MBW can also mean moving between different representational worlds – REP (Mavhunga, 2012). For example, having an oral explanation of how the electric circuit works, then showing it through a demonstration/picture/video and then drawing the electric circuit on the board to indicate all the shown components, as was observed with some teachers in this study.
	Writing scientifically	SP-WS	The teacher shows learners the correct way to write/represent, for example, a description of electric current flow in a circuit. It could also be writing down a scientific definition (electric current, potential energy, etc.), scientific process (flow of current in an electric circuit, etc.); scientific symbols through calculations, etc.

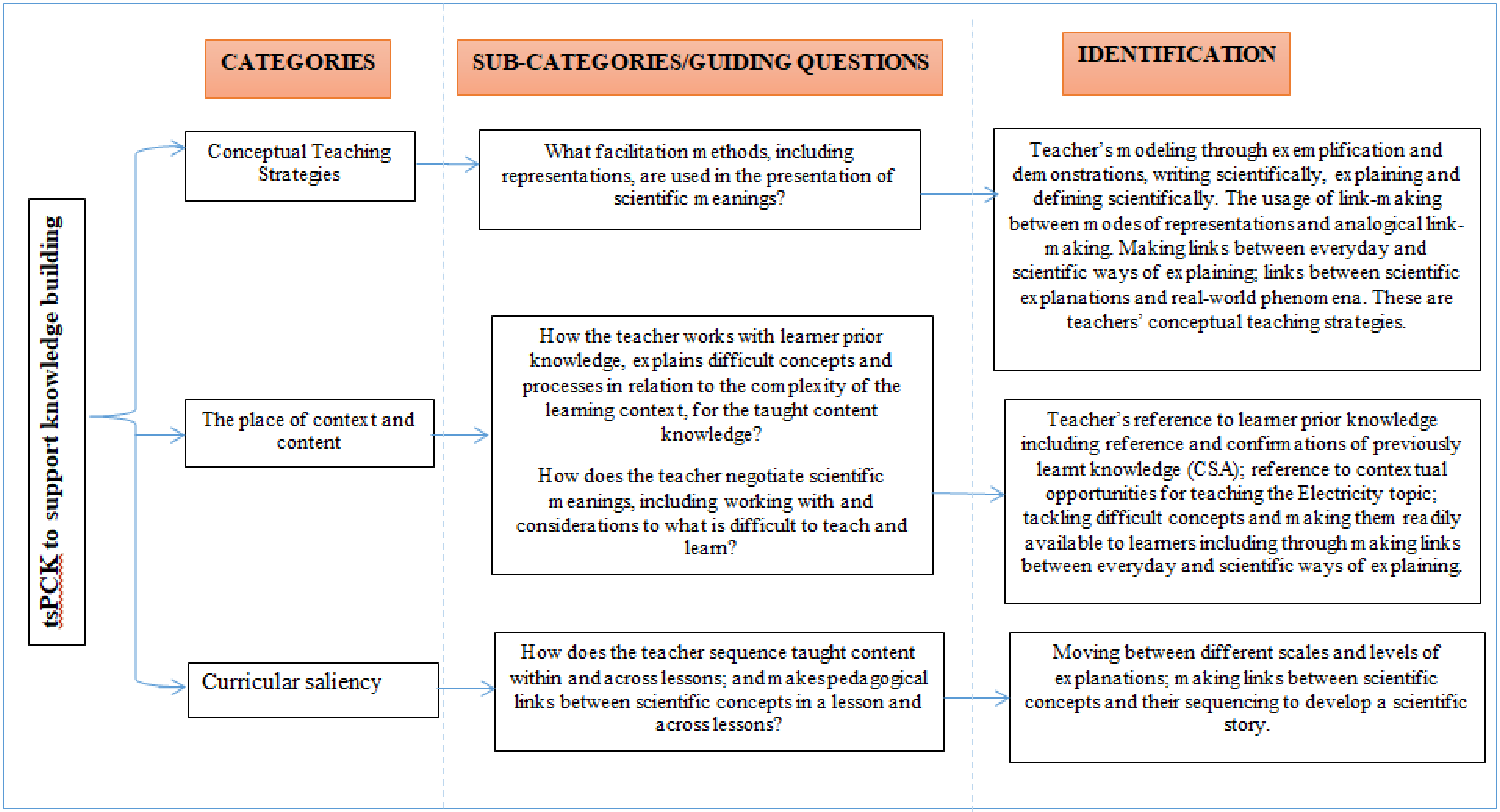
	Exemplifying (providing examples and analogies)	SP-E	When the teacher and/or learner provides an example to demonstrate a scientific method (e.g., an example of an application of a scientific procedure) and in concept development to indicate scientific relations (e.g., examples of a concept like voltage in relation to current and resistance). It could also be when a teacher or learner demonstrates how something is done in science, e.g., how to draw field line patterns between like and unlike charges, how to connect series and parallel circuits. An explanation can be made through the provision of an example. Use of words like: ―like…‖, ―for example‖. It can also be a call by the teacher or learner for someone to give examples. This category also includes analogies used in the classroom. For example, when a teacher explained the idea of internal resistance in an electric circuit by referring to pouring 20 litres of water in a pipe and later collecting less than 20 litres of water at the end of the pipe.
	Experimenting	SP-Exp	When the teacher or a learner performs an experiment including a demonstration like connecting an electric circuit. It could also be visually showing learners components of a circuit.
Scientific story development	Summarising:	SP-SB	When the teacher summarises what has been discussed on the board (by writing), orally, and reiterating. (For example: ―I am going to write down what we have said so far‖. In some cases, as observed in this study, the teacher would also write down the notes on the chalkboard and summarise verbally).
	Proceduralising	SP-Pc	When the teacher deals with the procedure/steps for solving a particular scientific problem. For instance, if the teacher talks about making current or resistance the subject of the formula when solving either I or R from the V=IR equation. Could also be a call for a particular procedure or aspects of the procedure to be used in solving a scientific task. For example, ―Where do we start? (which calls for the first thing that needs to be done by way of procedures) ―What do we do next?, ―What do we make as the subject of the formula? ―How did you get this answer?

5.5. The role of context in Electricity topic teaching

Though context is not explicitly acknowledged in tsPCK and/or PLM, it was however, important in this study as teachers referred to it as one of the dominant factor shaping what (content knowledge) and how (pedagogy) they teach Electricity topic. Therefore, the place of context and content was considered in the analysis and discussion of this study. Context establishes meaningful links first with teachers' school teaching context and their learning experiences; links with learner prior knowledge, including their everyday experiences; and promotes connections between prior knowledge, skills, and backgrounds (Choi & Hannafin, 1995). As indicated in Figure 8, to analyse each teacher's pedagogical practices in relation to context and content, the following guiding questions were asked: How does a teacher works with learner prior knowledge, including the uniqueness and complexity of the learning environment? And also how does the teacher negotiate scientific meanings, including working with and considering what is difficult to teach and learn? To help respond to these questions, classroom practices were scrutinised, with the focus on teachers' reference to previous knowledge learnt; reference to contextual limitations and opportunities for teaching the Electricity topic; and teachers' strategies for handling difficult concepts and making them readily available to learners.

Figure 8

Analysis of tsPCK to support knowledge building for the observed classroom practices



5.6. Chapter Summary

Providing the analytical language developed through the interplay between the theoretical frameworks and the actual classroom practices was the main aim of this chapter. The frameworks that enabled the construction of the analytical language were Mavhunga‘s concept of tsPCK and Scott et al.‘s concept of PLM pedagogical link-making. These frameworks guided the episode identification from classroom practices and helped develop the coding system of the data for analysis, including the construction of an analytical tool (understanding classroom practices). This chapter has also indicated how the methodological and analytical approaches helped me with data analysis. Chapter 6 presents the actual analysis and findings of the first case: teacher Amanda.

CHAPTER 6

Amanda's tsPCK to support Electricity knowledge building: Data Analysis

6.1. Introduction

The current chapter presents Amanda‘s analysed enacted pedagogical content knowledge, as was captured in the video recordings during the teaching of the Electricity topic in Grade 10 physical science classroom. This pedagogical analysis presents what the teacher said and did; the development and facilitation of concept formations and understanding, the pacing and sequencing of the content during each lesson. The classroom observation and video-stimulated recall interview data sets were analysed through tsPCK, PLM, and communicative approaches. Each observed lesson was organised into different but interconnected teaching episodes and were analysed in detail in this chapter. I begin the chapter by outlining the three observed Amanda‘s lessons with a brief description of the focus for each lesson.

6.2. Amanda's classroom practices: Lesson observation narratives

Three lessons were observed from Amanda‘s teaching and a total of eleven teaching episodes were identified from these lessons and analysed. Amanda‘s first lesson was taught in the classroom context and it was an introductory lesson to current Electricity, particularly components of the electric circuits and the relation between potential difference, energy, and charge (V=W/Q) even though the lesson was titled ―*electric circuits*‖ from the chalkboard. This lesson came immediately after a lesson on electrostatics hence it was an introductory lesson to *current Electricity*. This lesson was taught on a Monday morning in the first school period (8am-8:45am) though the lesson run for 52 minutes, 11 seconds. While learners were still settling down, the teacher had already started recapping on Grade 9 content followed by the initiation of classroom talk through questioning. The teacher began by demonstrating electric circuit components individually, and then wrote notes on the chalkboard focusing on what electric circuits are, the potential difference, and emf. Amanda then drew simple open and closed electric circuits to demonstrate the ideas of emf and potential difference, while also introducing the V=W/Q equation which she then solved exemplary mathematical problems where V=W/Q was applied. The last part of the lesson was a class activity testing learners‘ understanding of emf, potential difference and V=W/Q application. Learners did this activity and the teacher working with learners did corrections on the chalkboard. The interactive/authoritative communicative approach was dominant in this lesson and followed the IRF patterns.

The second observed lesson, titled ‘electric current‘ on the chalkboard, was taught from the science laboratory. The lesson lasted 52 minutes, 21 seconds. The I=q/t equation was explained first and followed by drawing a simple electric circuit on the chalkboard to show the positioning and connection of an instrument that measures current (ammeter) in a circuit. From the above practice, the teacher then wrote exemplary questions and solved them on the chalkboard. These questions required the understanding and application of I=q/t. This was followed by the teacher demonstrating for the learners and later called a group of learners in front to do a demonstration for other learners. The demonstrations focussed on simple series and parallel resistor connections in a circuit. The teacher ended the lesson by writing a class activity on the chalkboard for learners to copy the questions and respond to in 14 minutes, even though corrections were not done in this lesson but in the third lesson. Amanda continued to use mostly interactive/authoritative communicative approach but with the dominance of IRE patterns of discourse.

The third lesson was conducted in the classroom and it is a continuation from lesson two. This lesson lasted for 26 minutes, 22 seconds and it was not titled on the chalkboard even though the teacher made utterances suggesting that the lesson would be based on corrections on a previously given task with the continuation of the concepts of series and parallel resistor connections analysed mathematically. As such, calculations analysing resistors connected in series and connected in parallel were foregrounded in this lesson. In the process, the teacher explains the concept of resistors connected in series and directly involves learners in the process of calculations. The teacher leads learners in a step by step process with calculations on the chalkboard. It is because of these activities that I included the lesson because of teaching the content on series and parallel resistors through the activities in this lesson. Below I analyse Amanda‘s first observed lesson.

6.2.1. Lesson 1: Foregrounding learners' prior knowledge to promote Electric Circuit content and concepts continuity

Lesson 1, episode 1

The lesson 1, episode 1, focused on how Amanda linked previous content that focused on stationary charges to connect with the new content on moving charges at macro and meso-scale levels to promote content and concepts continuity, while helping learners to remember and notice the interrelationship between previous and current concepts by constantly making reference to the learners' prior knowledge (LPK) from within and across the school grades.

> **Amanda:** Yesterday we had finalized electrostatics, I know that you know that there are two types of charges. Which are the two types of charges Grade 10? Hands up! Miss Ayanda[28]. [**Ayanda:** Positive and negative charges]
>
> **Amanda:** Yes we do have the charges, positive charge as well as negative charges. As we know that in electrostatics, this is a form of electricity which is not moving, where charges are stationary and then in order to have a charge in electrostatics where electric charges are not moving we said we can accumulate a charge of an uncharged material or insulators, where we find that an object is said to be neutral and then we want to charge positive or negative. So we said there, you can charge through rubbing or through friction. In Grade 9 they do talk about the form of Electricity which is moving what do we call the form of Electricity which is moving, which has got charges that are moving? In Grade 9, do you remember? (*No response)*. Where we talk of the continuous movement of charges, so that is electric current. This is what we learnt in Grade 9. I want us to look at something that we looked at in Grade 9. We talked about electric circuits, this is Grade 9 work.

From the above excerpt, Amanda solicits learners' prior knowledge (LPK) of electrostatics concept done in the previous day and emphasises on the important ideas of static electricity necessary to build towards current electricity. The teacher used the mixture of initiation-response-evaluation and feedback (IRE/F) patterns to assess how much knowledge learners still remembers about the content, by making references to teaching and learning in different parts of the physical science curriculum (macro) and across lessons (meso) (Scott et al., 2011). The use of meso and macro levels was to draw learners' attention to the connection and continuation of science story (stationary charges to charge flow), to introduce the current lesson of Electricity and linking it with the upcoming lessons – electric current. Also, with reference to charge movement, the teacher explicitly makes links between electrostatics and electric current, which was a process of ongoing meaning-making in physical science lessons. The reiteration of Grade 9 work in the first episode was to prepare learners for the

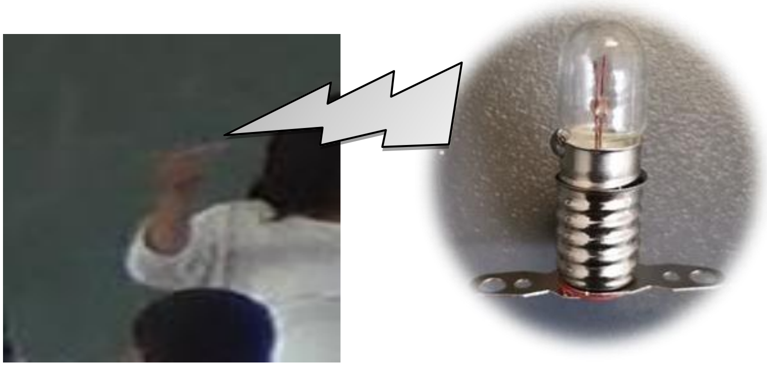
[28] Ayanda is a pseudonym given to the learner called by the teacher

demonstration of different components for electric circuits, as Amanda stated during the VSRI that these components should be known to learners '*because it is Grade 9 work, even in Grade 8…*' (Amanda). Thus, episode two focused on demonstrating electric circuit components and explanations of their usage and importance.

Lesson 1, Episode 2

In this episode, Amanda used different science tools in the classroom to demonstrate the components of electric circuits to the learners, before teaching the content. Amanda was standing in front of the classroom from the beginning of the demonstration, facing down and focused on the various components that were too small and not visible for the learners who were sitting at the back of the classroom. The teacher did not call learners in front of the classroom if the intention of the demonstration was to expose learners to the different science components. Amanda continued to connect Grade 9 work with Grade 10 content, after realising that she cannot assume that learners remembers the previous knowledge, including the learners she taught.

> **Amanda:** So here with me I have a circuit board, this is my circuit board *(raising it up and showing learners)*. And here I got some components which are found in a circuit, as you know that in a circuit we arrange cells, light bulbs, connecting wires, in order to see the flow of current. So this is my circuit board *(Photograph 12)* and in Grade 9 we talked about the light bulb, but I'm going to show you the components first so that it will be easier. These are the components, the light bulb *(Photograph 11)*.



Photograph 11. Amanda showing miniature light bulb to her learners

> **Amanda:** We do have connecting wires *(not visible to the camera)*, and then we do have a cell holder *(shown and quickly returned back)* and then we know this is a? [**Learners chorusing**: 'A cell']. This is a cell, when we've got two or more cells together they form a battery (see Photograph 13). And then in Grade 9 you also talked about components which are found in a circuit, this is an ammeter (see Photograph 14), an ammeter measures current. Also recap from Grade 9, we talked about a voltmeter (see Photograph 15), we said this is an instrument which measures what, potential difference, and then we said it is always connected in parallel and an ammeter is connected in series. That is a Grade 9 work that we have done

with the learners who were with me. These components have got symbols to represent with, we have symbols.

This is the side view of the circuit board, said the teacher, while lifting it up.

Photograph 12. Amanda showing a circuit board[29]

Photograph 13. Two 1.5V Cells

Photograph 14. Ammeter

Photograph 15. Voltmeter

Amanda: When you look at electric circuit, what is the role of electric circuit? It allows charges to move through. If I can connect all these components here *(pointing at the front desk)* and then what will happen, the charges will move and know that those charges that are moving, these are the positive charge as well as negative charge. And then how is this flow of charges? We said it moves from positive to a negative terminal of a battery. This is a positive terminal of a battery (+ terminal of a cell) and a negative terminal of a battery (- terminal of a cell) *(showing learners while standing in front desk of the classroom),* so that we call it conventional current. I said the role of an electric circuit is to allow charges to move through. We do have a switch, you remember a switch? [**Learners chorusing**: _Yes‘]. Right a switch can be opened or closed as you please and then its role...this is a switch[30] you can see it. You close the switch and then you find that the light will glow, if you open the switch there will be no flow of current and the bulb will not glow. Alright, that is what is happening here (*pointing at the classroom switch*), now the switch is closed and then you see current is flowing (with lights on) and then I close (*teacher switched off lights*), I‘m closing the switch but now the switch is open, you see if its closed (*then switching on the lights*), there is a flow of current.

[29] I noticed that the circuit board was small for the learners who were seated at the back of the classroom especially when considering the 85 learners in Amanda‘s classroom, as I was also stationed at the back of the classroom.

[30] Amanda shows a circuit switch to the class and it was too small to be captured in the video camera but went on to demonstrate how a switch works using the classroom switch on the wall (Photograph 16).

Photograph 16. Teacher switching on and off the classroom switch

As mentioned earlier, this demonstration happened before Amanda taught the content about electric circuits. From the episode and confirmed during VSRI, the teacher explained that she is showing learners the electric circuit components first because it will be easy for them to understand the electric circuit content once they have seen its components. During her demonstrations, the teacher constantly recaps by telling the Grade 9 Electricity content so that ―*…a learner can collate what is in Grade 9 with what is in Grade 10…(also) if the teacher didn't teach this Electricity part, that is when we need to recap back again…*‖, as the teacher argued for her teaching approach during the VSRI. The pedagogical choice represent one of the decisions a teacher makes about teaching the topic, possibly based on the careful thinking and lesson planning, and also previous teaching experiences of the topic. As the literature (Kucukozer & Kocakulah, 2007) argues that this section of closing and opening switch is usually challenging, addresses Amanda's combination of recognising what is difficult to teach and learn (WDT/L), the importance of careful use of the representations (REP), and the conceptual teaching strategies (CTS) to build science knowledge.

There was also careful consideration that learners sometimes forget what was done in previous years, including previous week, making it important not to assume as a teacher but recap to show concepts continuation. It is unfortunate that Amanda used small resources for demonstration, which highlight some of the rural school's challenges with science materials. The teacher improvised and used what she had, and could have called learners in front, in groups if they were too many, to demonstrate the resources. Moreover, the demonstration started by showing an electric circuit board followed by a miniature light bulb, then the connecting wires (copper strips) which were not visible for the video camera, then a cell holder. All these happened quickly without the explanation of what each component does (their function in an electric circuit), except when Amanda showed the ammeter and a voltmeter. The two instruments were explained in detailed, stating what each does in an electric circuit.

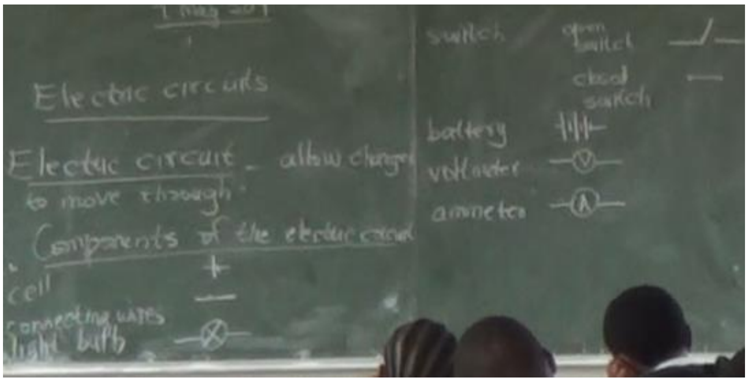
Furthermore, it was interesting to observe Amanda making links when explaining to differentiate that voltmeter is always connected in parallel while an ammeter is connected in series in an electric circuit. This episode was dominated by teacher talk, while learners sat quietly listening and observing what the teacher was saying and showed them, because Amanda wanted to connect the demonstration with the content to be taught in this lesson and subsequent lessons of Electricity topic. Dominantly, the teacher was asking and responding to her questions, without ‗inviting' and/or giving learners the opportunity to try and respond. Thus, the nature of interaction was learners completing sentences and confirming closed questions that were evaluative, and the authoritative aspect was the teacher focusing on presenting science ideas without being disturbed. I observed that while Amanda made a clear distinction between a battery and a cell previously in episode one including in this episode, she later used the terms battery and cell interchangeably, without noticing. This statement does not overlook the complexity of teaching, that sometimes teachers are always conscious during the lesson.

To link the complexity, I further observed that in episode 1 until this episode, the teacher has been referring to flow of charges, and changes to flow of current, without making a coherent scientific story by linking the flow of charges and flow of current. Lack of a clear distinction and linkage between the two concepts might add challenges for learners and the teacher when discussing conventional current later. Additionally, Amanda used the switch in the classroom (Photograph 16) to demonstrate a difficult section of the topic, making links between scientific explanations and real world phenomena, because of everyday ways of explaining which differs from the scientific ways of explaining the concept and process of closed switch and open switch. The representation of what is difficult to teach (WDT) was observed when Amanda struggled to explain this process while demonstrating using the classroom switch, resulting to misinterpretation of the concepts. The teacher noted the mistake and difficulty to explain this process, as her face showed confusion during the explanation.

Interestingly, during the VSRI, Amanda was aware of the difficulty to explain and understand the relationship between current flow and a switch in real world operations. This is seen when Amanda states ―*I wanted learners to know that when the switch is closed, current will flow, because they might know that open switch means there is a flow of current. Then if it is closed there is no flow of current*…‖ To reinforce understanding of electric circuit components demonstrated, Amanda made explicit links between different modes of representations (REP) as she moved from the macroscopic to symbolic (diagrammatic) representation of the circuit components. The following episode demonstrates how Amanda symbolically approached circuit components. This part of the lesson used non-interactive/authoritative communication approach, because of the teacher‘s goals, even though it contradicts with the pedagogical link-making to support knowledge building by making links between everyday and scientific ways of explaining and making links between scientific explanations and real world phenomena (Scott et al., 2011).

Lesson 1, episode 3

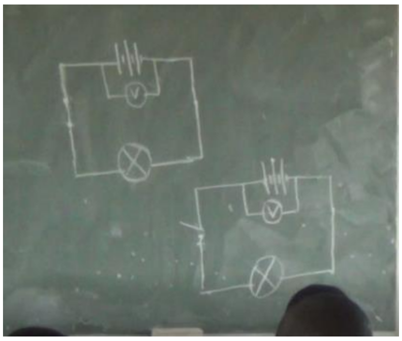
In this episode Amanda used different modes of representation when she wrote the names of electric circuit components on the chalkboard for learners to see and copy to their notebooks, then drew the symbols (Photograph 17) of these individual components on the chalkboard and then holistically into a circuit (Photograph 18 & 19), and then the use of science discourse was encouraged by the teacher. With the latter, she was introducing learners to the way of talking and thinking about scientific processes to connect components into a complete electric circuit. Below is the extract for episode 3,



Photograph 17. Electric circuit components‘ symbols

> **Amanda:** We represent these components using symbols. So there are symbols that we use in science so that we know what we are talking about. When you are talking about a cell, this is a positive terminal and this is a negative terminal (*as shown in Photograph 13*). And then when you got more than two cells, it is no longer a cell but it is a… [**Learners chorusing**: Some say cell while others say a battery]… A battery, this is a symbol which shows a battery (*pointing at the battery symbol on the chalkboard*) it can be two, three or more. Then we have a voltmeter, how do we represent a voltmeter? This is symbol V, a voltmeter. You recap Grade 9‘s work. A closed switch, this is a symbol for a switch (*pointing at the drawn line with two dots in Photograph 18*) which we said it is closed. In a closed switch, there is a flow of what, of current. And then we have a switch which is open (*teacher draws an open switch representation*). In an open switch there is no flow of current. Let me make a diagram which

will illustrate a cell which is said it is connected and is complete (*the teacher draws the two diagrams on Photograph 18*). This is my circuit diagram (*referring to Photograph 18*).



Photograph 18. Closed/Open Simple circuits

Photograph 19. Labelled Simple Circuits

Amanda: So now we want to differentiate between the two of these circuits, here we do have what? (*referring to the first diagram A in Photograph 19*) [**Learners chorusing**: a switch]. What can we say about the switch between the two circuit diagrams? So for circuit diagram A, this is my A and this is my B (*labelling the diagrams as indicated in Photograph 19)*. What can you say about the switch? Say something about A. [**Learner**: The switch is closed]. The switch is closed, so what tells you when the switch is closed? [**Learners chorusing**: There is a flow of current]. There is a flow of current, so here there is a flow of current (*writing next diagram A*) and then what did we say about the switch?

[**Learners chorusing**: It is closed] The switch here is closed (*verbalizing as she writes it on the board*). Diagram B! [**Learners chorusing**: The switch is open]. So here we have open switch (*verbalizing as she write it on the board*). Say something about this circuit. [**Learners chorusing**: There is no flow of current]. There is no flow of current. Now if the cell is completely connected you will find that there is a flow of current like diagram A *(Photograph 19*). So, if there is a flow of current, like diagram A, we talk of potential difference. So now we are talking about potential difference. Here we got a circuit but now we find that the charges are not moving so there is no flow of current. Like here I do have my battery (*pointing at diagram B of Photograph 19*), my battery is there, it‘s the voltage, it is not being used. So now we are talking the emf. We are talking about the potential difference (*pointing at diagram A*), and then we are talking about emf (*pointing at diagram B*). So in other words, when we look at the emf, we are talking about maximum voltage that a battery can deliver. So if you go to town, you buy your cells (*showing a 1.5V cell*) its 1.5V or 3.5V. If these cells are not being used we say it has got emf because it is not used but if you take that battery and then now you connect it completely in such a way that the charges will move, we said they move from positive terminal to the negative terminal. And then now, we will find that we are talking about potential difference. So in other words, now it means the battery is working so charges now are moving, so that‘s the difference between emf and potential difference. I am going to write that on the board. So you have to know in Grade 10, what is the definition of potential difference, what do we mean when we talk of potential difference.

Amanda showed learners how to symbolically represent and talk about electric circuit components, and emphasised the importance of symbols as a representational language of the components for electric circuits. From the beginning of this observed episode, the demonstrated components and drawn symbols were not yet integrated into an electric circuit representation but were discussed independently from the electric circuits and electric circuit connection. When asking about more than two cells, Amanda was holding one cell, which was possibly the reason some learners responded ―cell‖ instead of ―battery‖, while some responded correctly. The learners' responses to the teacher's question seeking to differentiate between a cell and battery indicate that some learners appeared to understand the teacher's explanation of what a battery is, while some learners appeared to have misunderstood the teacher or relied on what was shown at the time of questioning. Continuing with the lesson Amanda talked about a switch and electric current and projected a switch as a complete circuit of its own, such that if it is closed then there is flow of current but when opened there is no flow of current. This presentation could be misleading to learners, because a switch is an electrical component that is used to disconnect or connect the conducting path in an electric circuit. I noticed that this way of talking about the switch could be one of the limitations of discussing components of electric circuit independently from the electric circuit.

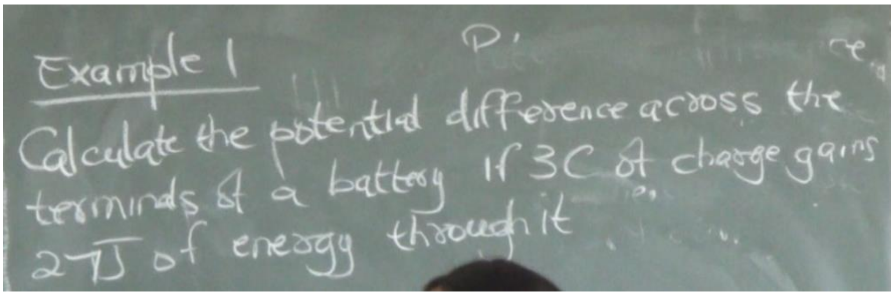
After Amanda has drawn the electric circuit components individually (Photograph 17), she then put them together to make a circuit in Photograph 18 and 19. The teacher's intention of drawing the two circuits in Photograph 18 and 19 was to show the idea of open and closed switch in relation to current flow in a circuit. It was then interesting to see learners responding to Amanda's questioning of closed switch by stating that the switch is closed because there is no flow of current in the drawn circuit and Amanda confirmed this response as correct. Similarly with the open switch question, learners responded ‗there is no flow of current'. Of concern however, was overlooking the presence and role played by other components (power source, resistor, and connecting wires) in completing a circuit for flow or no flow of current. How learners therefore deduced the relationship between switch and current flow was not clear. Moreover, Amanda links the flow of current in a closed electric circuit to potential difference by referring to diagram A in Photograph 19 while open circuit in diagram B of Photograph 19 is linked to electromotive force (emf).

The teacher's classroom talk about the closed and open circuits when presenting the definitions of potential difference and emf was descriptive while the written definitions on the chalkboard were concise using scientific discourse because learners copied them as notes. This addresses the differences between teacher talks which might be descriptive and written notes where a teacher is aware that they represent explicit detailed information for future use (assessment, studying purpose to immerse oneself to scientific discourse). Furthermore, when Amanda verbally explained the differences between potential difference and emf, she moved between the symbolic (battery – Photograph 18) and macro representational levels (showing a 1.5V cell as in Photograph 13) to emphasise the described phenomena. Thus, in this episode Amanda developed a micro scientific story by first drawing the electric circuit components discretely, then put them together in electric circuit diagrams, and described the connections in relation to current flow or no flow.

Similar to episodes 1 and 2, the teacher dominated this episode 3 while learners were sitting quietly watching the teacher and then taking notes. Where Amanda initiated classroom talk through questioning, learners' participation was through short answers that served as confirmations of the teacher's ideas. Towards the end of the episode, Amanda wrote some notes on the chalkboard which summarised the explained ideas of electric circuits, emf, potential difference and terminal potential difference for learners to copy into their notebooks. Notes were written word-to-word on the chalkboard because '*there is a shortage of textbooks*' and that learners '*need the chalkboard summary*' of work done because '*if the advisers (department officials) come, they need the summary of the days…they want to see where and when did you do this*', teacher Amanda reasoned during VSRI for the process of this episode. After writing the notes on the chalkboard the teacher did an example of how to solve potential difference and then summarised the content she has covered in this lesson. The following episode shows how the teacher approached problem solving and summarising of lesson content. Summarising a lesson is important because the teacher could highlight the Big idea(s) of the lesson in this section and it can help find out what learners have internalized, understood, and remembered, while exposing possible learner confusion, misconceptions, or misunderstandings so that the teacher could adapt future teaching accordingly. The differences in the way teachers completed lessons/episodes will be discussed in the discussion chapter (chapter 9).

Lesson 1, episode 4

In lesson 1, episode 4 Amanda used the activity-based approach where exemplary questions written on the chalkboard (see Photograph 20) were used to summarise the content knowledge about potential difference. After the exemplary problem solving, the teacher summarised content covered in the lesson, with the focus on linking the concepts of charge flow to potential difference, instrument used to measure potential difference and how this instrument is connected in an electric circuit. The teacher used the task and lesson summary to consolidate potential difference content knowledge explained and that written as notes in the previous episode 3, the relationship between the concepts of potential difference, work done, and charges through calculations. Following is the extract for episode 4:



Photograph 20: Potential Difference activity (example 1)

Amanda: Now if 3C (*underlines*), you are given that is your data, 3C is what? [**Learners:** Charge] The charge in Coulomb. So in other words we are given our charge. Again 27 Joules, you know the symbol J, its for? Work, so this is our work done. So we do have our charge, we do have our work done. So it is easy for us to calculate potential difference using the formula V=W/Q (*as she writes the formula on the board*). What is our work done, 27J, what is our charge, 3C then you divide, use your calculator 27 divided by 3 [**Learners**: Its 9]

Amanda: Because we are not going to write 9, this is not maths but you are calculating what? Potential difference, so the units of potential difference are Volts. So it is not correct to write only 9…ok that is example number 1, is it clear? [**Learners**: Yes] Let us do the last one. This is another example, we have to engage ourselves in doing calculations based on potential difference … what is the potential difference of a light bulb if a charge of 17.5 Coulomb pass through it and radiate 4200 Joules of energy. Who can tell me, what are we given? Hands up **(***No response*) Look at the example given and then give me what is given. (*No response*) what is given? There on the example look at the data, what are you given? [**Learner**: you are given the charge] You are given the charge then what? **[Learner:** work done in joules] Work done in joules so we can calculate the potential difference, can you just do that calculation I am going to give you 2 minutes so that you can share if you have done it correctly. You can work with someone next to you, to see if you do understand because this is straight forward. *(3 minutes later)*

Amanda: Others are finished, what did you get? [**Learners:** 240] Let‘s see, using the formula V=W/Q, what is our W? [**Learners**: 4200] What is our charge flowing? [**Learners:** 17.5] And if you divide this, what did you get? [**Learners:** 240] Alright clap hands for all those who got it correct. But I‘m not happy because they just doing it randomly, I had to check using activities so that I can see if you have mastered what we have learnt today.

Amanda: Now let us summarise this. We have been talking about electric circuit, we have been saying they allow charges to move through, we know the types of charges and then we know about the components of a circuit…

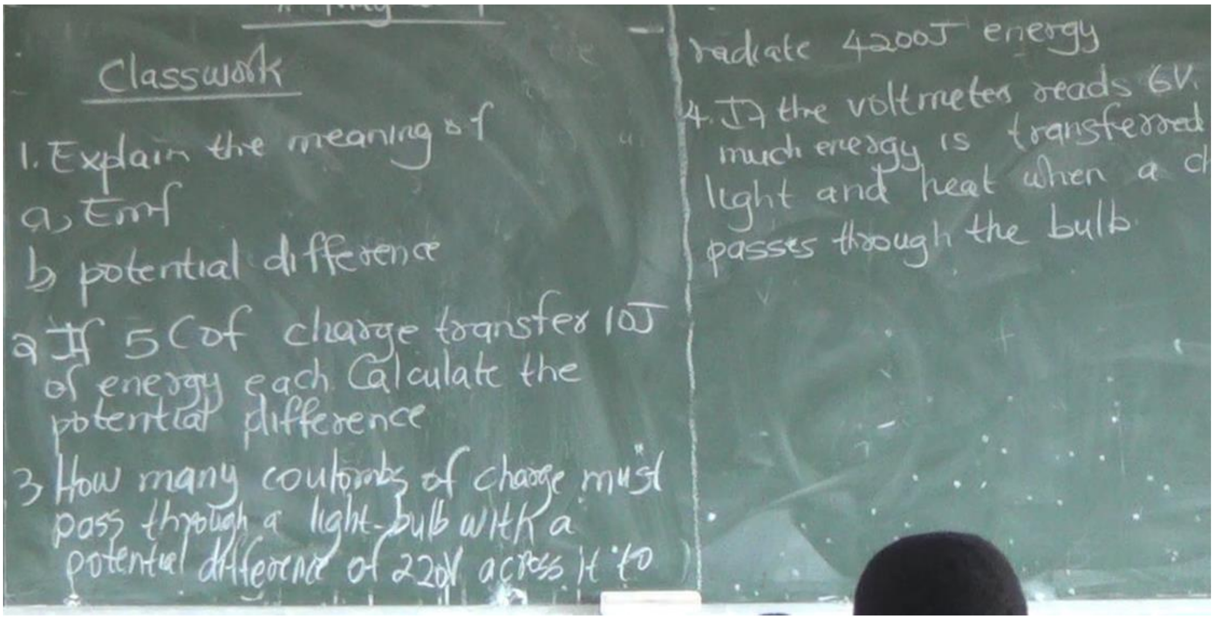
In this episode, Amanda introduced the first problem solving in current electricity topic and models the scientific thought processes underlying the problem solving process. She foregrounds ‗data' (given values) and emphasised the importance of calculation using this data. Through this problem solving, there was an introduction of calculations, where the formula V=W/Q was applied in the continuation of the scientific story from episodes 1 to 3. Amanda dominated the problem solving practice representing non-interactive/authoritative communicative approach, to show learners how to engage with the calculation process using correct concepts and differentiating science and mathematics practices – scientific discourse (SI Units on the calculated answer). The non-interactive/authoritative communicative approach only fosters scientific point of view, as the teacher is concerned with the development of the school science point of view only, or the scientific story (Lehesvuori & Ametller, 2021). I observed that in the explanation and description of potential difference in lesson 1, episode 3, Amanda did not teach about SI Units for potential difference or its importance in calculations, but in this episode she required learners to include this important information in the calculation-based example and emphasised (CSA) on its importance. These SI Units might have been taken for granted during teaching but the problem-solving calculations serve as a teaching opportunity for Amanda. The first task in Photograph 20 was to model how learners needed to solve a problem in science including calculations, while revisiting and recalling concepts that were done in episodes 1 and 2 and link them with the task. It is thus not surprising that the episode was dominated by teacher talk and learners were involved to do calculator-based contributions and to confirm teacher's elucidations, a continuation from previous episodes' teaching approach.

Moreover, Amanda used the first task as an example to induct learners and further used it to refer learners for the second task, as they appeared to have forgotten how to engage with the calculations. It was interesting and concerning while learners forgot what the teacher taught them in few minutes when she needed them to respond to the second task. Task 1 and 2 required similar approaches where work done and charge were given in both scenarios and learners had to calculate the potential difference. With regards to the second task, Amanda had to ask learners to infer on the previously solved problem in example 1 which was completed with the help of the teacher, to see what was given for potential difference calculation. It was not clear why learners struggled with task 2, whether it was because of the teacher's approach or learners' inactive participation during teaching and learning process and VSRI did not provide insights to this aspect of learner difficulties.

Thus far, it was interesting to observe that the teacher has demonstrated the components of electric circuit; introduced the idea of simple electric circuit; wrote notes focussing on *work done* and *potential difference,* which then led to the classroom activities on potential difference and its relations with charge and work done. After the tasks had been completed, the teacher summarised the content of this lesson focussing on maintaining the scientific story of charge movements, work done and potential difference. In her content summary, Amanda asks questions about the definitions of emf and potential difference. After content summary, the teacher gave a class activity to assess learners' understanding of the concepts and calculations that were taught and demonstrated during the lesson. What is different now is that learners are working individually in solving the classwork problems. Photograph 21 shows the class activity written on the chalkboard by the teacher. Of interest, VSRI exposed the teacher's previous knowledge or teaching experience of the Electricity topic as she argued that '*this method of teaching first, then examples and class activities has been working for me…'* in the previous years of grades 10-12 teaching.

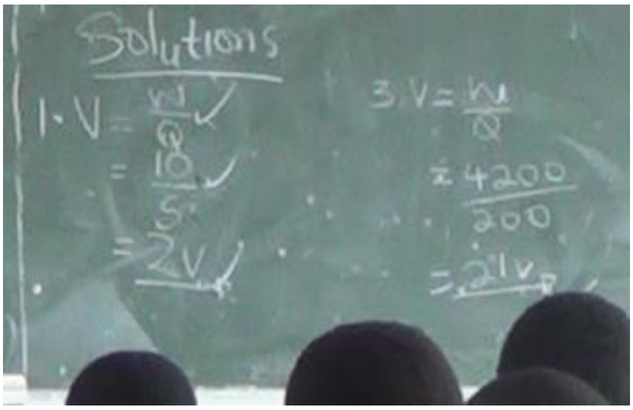
Lesson 1, episode 5

This episode shows how Amanda worked with learner's prior knowledge (LPK) when developing a scientific story for continuity at micro-time scale. Beyond the lesson summary in lesson 1, episode 4, classroom tasks were used to consolidate the work covered in the lesson and to check learner understanding. In this task, questions were structured according to Bloom's Taxonomy, with questions ranging from the remembering (recall) to application of the learnt content knowledge and skills regarding the V=W/Q formula and its application for calculations. Learners were then given 14 minutes to copy the questions from the chalkboard and write solutions of each question shown in Photograph 21. Learners were asked to write problem-solving solutions on the chalkboard. Of concern, when writing solutions on the chalkboard, there were no explanations of learners' understanding of the undertaken procedures. Instead, Amanda monitored learner solutions and explained the procedure taken by each learner in solving the problems. In her explanations, I observed that Amanda was more interested with the application of the correct formula, correct substitution, and a correct answer but the scientific conceptual understanding was not explicitly enforced through calculations. The following episode 5 illustrates,



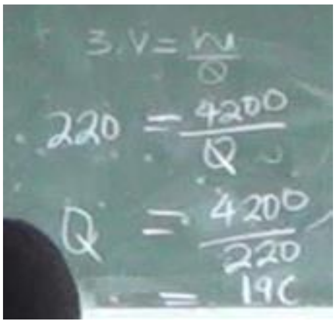
Photograph 21: Classwork task written on the chalkboard

Amanda: *Bathini ku number one* (what are they saying on number 1), the definition, no one? What is it, emf? Is the voltage measured across the terminals of a battery when there is no current flowing. And then potential difference? *Khulumani!* (talk!) What is it? The energy… [**Learners**: …Transfer per unit charge] Ok, we are done with number one. So let‘s look at number two, who can do number two for us on the chalkboard? Now using the formula V=W/Q, our work done is? [**Learners:** 10] Its 10 and then our charge [**Learners:** 5] Is five. When you divide, you get 2, so this is the answer.

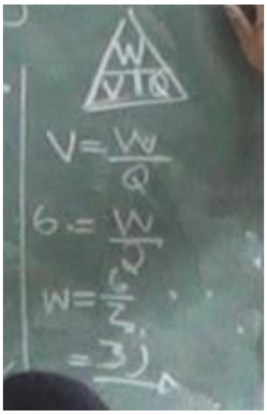


Photograph 22: learner‘s responses to question 2 and 3 from Photograph 20

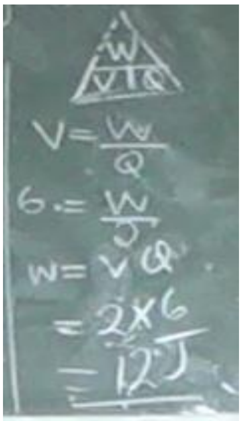
Amanda: Number three, what does it require? How many coulombs, it is the question. It wants what, the charge not potential difference. In other words you are not given the charge, we are given here the potential difference and energy. What is our potential difference, 220, what is our work done 4200, Q we are not given the charge. How do we calculate the charge, we say 4200 divided by 220, it will be… [**Learners:** 19 Coulombs]



Photograph 23: Teacher response after erasing learner response



Photograph 24: Mxolisi's response to Q4



Photograph 25: Teacher version of Q4 response

> **Amanda:** We normally use this (*drawing the triangle of W, V, Q as shown at the top of Photographs 24 & 25*). So now they are looking at how much energy, they are looking at work (*hiding the W symbol with a hand from the drawn triangle leaving V side-by-side with Q*), so for work it will be V times Q. It will be 2 times 6, it will be 12 joules.

The episode was meant for the teacher to work with learner prior knowledge (LPK) including misconceptions displayed through mathematical calculations on the chalkboard (symbolic REP's). While working with LPK, the interactive/authoritative communicative approach dominated the episode as the teacher led learners through a sequence of instructional questions and answers. Also, some aspects of evaluative approach were noted when the teacher went through learners' calculations on the chalkboard to assess whether and how equations had been applied, manipulated, substituted into, and final answer calculations. The first question of the classwork task was a definition-seeking question and Amanda defined emf and potential difference for learners after getting a no response from learners. It was concerning to observe the teacher not giving a waiting time for learners to respond to question 1a in Photograph 21. Instead, Amanda asked the question and quickly read the definition from her exam guideline. This is concerning when considering that the classwork task was based on the content taught in the lesson.

The teacher rushed through the definition-seeking questions towards calculation-based problems, of which the teacher encouraged learner participation by allowing learners to write problem-solving solutions on the chalkboard. The teacher reiterated and confirmed what had been correctly written by the learner in Photograph 22(1) while enforcing the scientific procedures in calculations. However, an interesting yet concerning practice is observed for questions 3 and 4 of the classwork where learners applied the same formula of V=W/Q but substituted values incorrectly. Amanda analyses the questions individually and evaluates each learners‛ responses. During the evaluation process, learner misconceptions (LPK) are addressed using symbolic REP that links scientific concepts (Voltage, Work done, & Charge) at the top of Photographs 24 and 25.

For both questions 3 and 4 in Photograph 21, Amanda emphasised (CSA) given DATA for each question while also focusing on linking key scientific concepts to be calculated, like coulombs and charge for question 3, and energy and work for question 4. After highlighting the key data for each question, Amanda erases the learner‛s solution without the mention of where the learner went wrong in the calculation. This action by the teacher could make learners inputs devalued and might limit their participation in the future proceedings. For question 3 in Photograph 23, Amanda solved the mathematical problem without an explanation or indication of the mathematical principle (cross-multiplication) that has been used. This practice does not promote deep understanding of scientific and mathematical processes, instead, it demonstrates fragmented presentation of knowledge when considering teacher action (written) and teacher talk (spoken). The taken for granted cross-multiplication principle in Photograph 23 resurfaced in the question 4 in Photograph 24, where a learner applied the formula correctly, substituted correctly but failed to apply the principle of cross-multiplication. This principle appears difficult for learners to learn (WDT/L) while the teacher takes it for granted that learners know it as the teacher never made mention of the principle. This marked the end of the lesson.

In summary, Amanda‛s first lesson focused on the introduction to electric circuit components, demonstrating how these components looks like. The components were then represented symbolically on the chalkboard separately and then integrated into electric circuit diagrams that focussed on current flow and electric switch. The concepts of emf, charge, work done, and potential difference (voltage), importantly their mathematical relation through calculations, were also the focus of the second part of the lesson. After which, calculations were done to solicit learner understanding of the taught content. Of concern, the teacher was at the centre of the problem solving while learners were at the periphery of the process. In the second observed lesson, Amanda explained and demonstrated the concept of electric current in relation to resistance in an electric circuit. The lesson is discussed in detail in the following section.

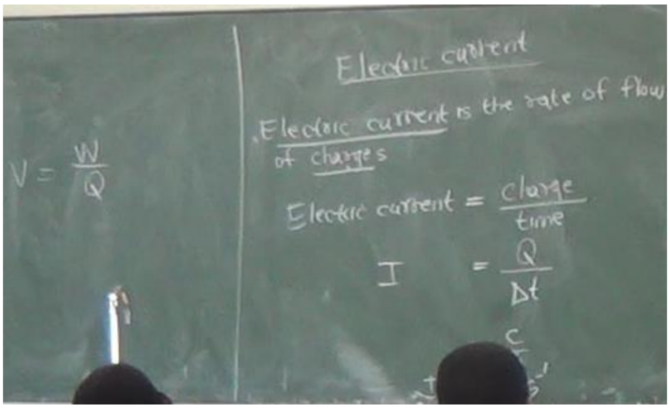
6.2.2. Lesson 2: Moving between symbolic and macroscopic representations for electric current

Lesson 2, episode 1

This lesson was taught in the science laboratory, and Amanda started by writing previous lessons content on the chalkboard with the focus on potential difference and EMF. She re-emphasised the concepts of the previous lesson and highlighted the focus of the current lesson, adding the definition of electric current and its equation. This was interesting because Amanda developed a scientific story from the demonstration of electric circuit components and calculations of the concepts for the work done, charge, and potential difference to the electric current. From recapping, Amanda drew learners' attention to the demonstrations of a complete electric circuit, which is the continuation from episode 1 of the previous lesson. In her introduction, Amanda starts by setting up a simple electric circuit on her front bench using the micro-electricity kit[31] and then says,

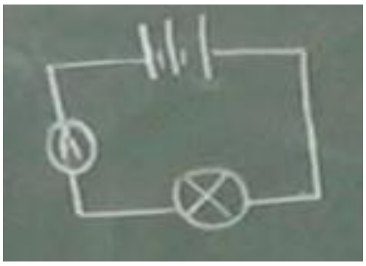
> **Amanda:** On Tuesday we were looking at electric circuits but our main focus was on emf and potential difference… So, for today we have to engage ourselves with electric current. For potential difference and emf, we looked at this formula, V=W/Q, where V is voltage, W is work done and Q is a charge in Coulomb. Now we are looking at electric current ehhm as you are here you are seeing that the light bulbs are glowing so there is that flow of current. So if we define the word electric current we said electric current is the rate of flow of charges, that you can express in equation (*writes electric current equals to charge over time*) this is the word equation of how to express electric current. It said it's a rate of flow of charges, how do we represent current, we use symbol I, for charge (*writes Q*) and then for time (*delta t*) this is the symbol for time. If we move on, what is the unit of charge Grade 10? [**Learners:** Coulomb]

[31] These are the Electricity-based apparatus as shown in lesson 1, episode 2.



Photograph 26: Introducing electric current

Amanda: …and then the unit of time it is seconds. Then we come up with C/s, so in other words (*writes* $I = C.s^{-1}$) the unit of current are Amperes, with symbol A. so our main focus today is to look at current being the rate of flow of charges, can be calculated using the formula I=Q/t, of which at the end the unit of current is Ampere. As you are looking at current, this current can also be measured, how do we measure current? We use the instrument called an ammeter, this is an ammeter (*lifting and showing to the class an ammeter*). This ammeter is connected in a circuit as we have said that a circuit allows what charges, how do we connect an ammeter? We said an ammeter is connected in which way? [**Learners:** Series] Series yes. Why do we connect an ammeter in series? If you look at an ammeter it has got a low resistance, if it has got a low resistance it means if you connect it in series you must make sure that you connect it at the point where you want to measure because if you connect it in parallel, what will happen, it will cause damage in the circuit because of that high current. So in other words, if I can draw a circuit diagram, I want to draw a circuit diagram first (*draw a simple circuit on the board as shown in Photograph 27*).


Photograph 27: Drawn simple electric circuit

Amanda: So this is how we connect an ammeter, this is an ammeter (*pointing at the symbol A in Photograph 27*) it is connected in series so in other words if you wanted to measure current here (*pointing at A in Photograph 27*) then you would put the ammeter at a point where you want to measure that particular current. We are not going to connect an ammeter parallel, why? Because an ammeter has a high current. So we need to connect it at a point. If you look at the voltmeter the last time, we said a voltmeter is connected in which way? [**Learners**: parallel] It is connected in parallel. Let‘s look at the diagram (*Photograph 28*)

Photograph 28: Demonstration of voltmeter‘s parallel connection

> **Amanda:** When you connect your voltmeter it is connected across, this is parallel (*indicating with her hands as shown in Photograph 28*) it is connected across the battery, an ammeter is always connected across the battery. So we said an ammeter is connected across two points but if you look at an ammeter, an ammeter is connected at that particular point you want to measure current. So, that is the difference between the series and the parallel, looking at the two instruments, the voltmeter is connected across and then we looked at an ammeter it is connected at a point in which you want to measure that particular current. So, we are going to do experiments where we connect like this (*pointing at resistors connected in series*). Make sure that you understand how do we connect an ammeter, how do we connect a voltmeter. So as you look at the diagram, that is the theory part of it, but you need to do it practically where you engage yourselves on seeing the amount of current, the voltmeter what happens to a battery when the voltmeter is there and then you check whether the switch is closed or the switch is open.

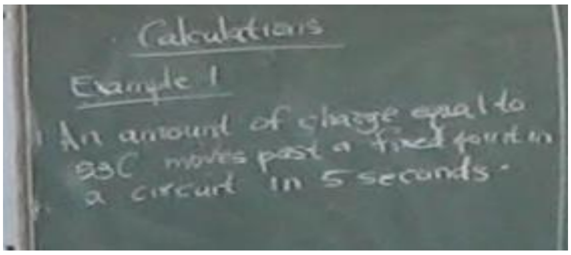
Amanda makes explicit links between the symbolic (equation & diagrams) and macroscopic levels of representations (voltmeter), building bigger relations between scientific explanations and the real-world phenomena using a glowing light bulb in the laboratory to talk about the flow of current. Following this link making was the introduction of electric current concept through a practical scenario using the laboratory light bulbs. Amanda integrates the abstract explanation of electric current with the symbolic representation as I=Q/t on the chalkboard, at the same time wrote the definition of electric current on the chalkboard which learners copied to their notebooks. This represented an introduction to the concept of electric current. The various symbols were described written on the chalkboard with the repetition of the lesson objectives, linking with the descriptions of the symbols. During this episode, Amanda dominantly used ‗self-answered questions' with limited learner participation responding to the questions, and constantly refers to the previous lesson which represents meso-level time scale (Scott et al., 2011). This represented non- interactive/authoritative communicative approach that was influenced by the teacher‘s intention to transmit facts and skills, even though not the relationship between them (Staarman & Ametller, 2019).

To re-emphasise ideas, Amanda used her hands (see Photograph 28) as tools to demonstrate the connections, reiterating important ideas to ensure that learners understand their importance. In the VSRI, Amanda called the whole demonstration and explanation process as ―theoretical‖, emphasising the role of practical to ‗see' the process in relation to theory. From the ‗theoretical' classroom practice, where Amanda explained the concept of electric current and the components of an electric circuit that measures current, she immediately wrote three examples on the chalkboard for calculations. The examples, as activities, were for the content knowledge of electric current to show how the electric current equations should be applied. The following section represents the second lesson, episode 2, and the problem solving examples which required the application of the explained I=Q/t equation in calculating electric current.

Lesson 2, episode 2

Immediately after writing the exemplary questions on the chalkboard, Amanda reads the questions, analyses the questions highlighting what is given and required to be calculated. The teacher leads all the problem solving processes in this episode. The following extract illustrates Amanda's practice with regards to exemplary problem solving.

Amanda: Alright as we are looking at electric current, you have to do calculations on how to calculate electric current. I have got an example, now let's do calculations (*and she writes the following on the board*):



Photograph 29: Exemplary problem solving question

Amanda: We have said that electric current is equal to a charge passing through a point over time. Of which is I=Q/t. now looking at our information, they say an amount of charge (*reading from the board*), so we are given what here? So in other words this is our Q that is the amount of charge that moves past a point in a circuit in 5 seconds, 5 seconds represents what? [**Learners**: time] Time. To calculate current, I=Q/t. what is our Q? [**Learners**: 53] Time? [**Learners**: 5] Then you divide. [**Learners**: 10.6] 10.6A.

Amanda: (*Teacher writes another example on the chalkboard and she says*) Ok that is another statement given here, an ammeter which is an instrument to measure current and you know that an ammeter is connected in series so it reads 6A, what quantity of charge so that is what is required they want us to calculate charge, It flows through the instrument in 1 minute, then you are given time which is 1 minute. 1 minute is equal to how many seconds? [**Learners**: 60 seconds]

Amanda: 60 seconds so we have to change. So now you can calculate (*she writes the current equation*) we are not given the charge, we are given current, our current? [**Learners**: 6]

Amanda: Charge not given, time 60, so we want charge. So the time I said if you use a triangular method it could help you (*she drew the following*)

Photograph 30: Solution to problem solving questions

Amanda: Let me do now the last example. Ok statement again (*as she reads the statement from the chalkboard*) a current of 10A flow through a light bulb for an hour. 1 hour equals to how many seconds? [**Learners**: 60 seconds] Angithi *(isn't)* the minute is 60, an hour? an hour? [**Learner**: 3600] Its 3600 seconds, so if its 2 hours it will be 2 times 3600, 3 hours it will be 3 times 3600 are you with me? [**Learners**: yes] Ok now calculate this, I=Q/t, and then we are required to calculate the charge so you are given current, the current is? [**Learners**: 10]

Amanda: Then the charge we don't know and our time is 3600. For charge it said (*pointing at the previous calculation*) I times t (It), which is equal to 10 times 3600, 3600C that is a large charge. You see its easy. Ohhh yes there is one zero missing *(added the zero to have 36000*). So this is regarding current, now we are done with emf, potential difference, and current.

Amanda led the process of identifying the given information in each question written on the chalkboard, led the process of converting given units to appropriate SI Units, while learners were more involved in the mathematical operations of the examples. This represented a non-interactive/authoritative communicative approach. She constantly repeated definition of electric current, connection of an ammeter in a circuit, and information she perceived as important, using micro level time scale to show learners how calculations work. All the questions were not only written on the board, but the teacher also read them for the learners, and wrote learners' responses as they were calling them out especially the mathematical operations. This means, during this time learners were involved in the activity by calling out answers and writing in their notebooks what was written on the chalkboard. All these happened in a fast pace, which was initially observed in lesson one, and included Amanda‘s continued ‗self-answered questions‘ approach, with learners confirming teacher‘s talk with one word items.

During the chalkboard activities, Amanda used Initiation – Response (learners) – Evaluation, because the purpose of the activity was to evaluate learners‘ basic understanding of the lesson, which linked with the link-making approach to develop scientific knowledge. I observed that in the last calculations learners appeared not to understand the answer and mumbled resulting to Amanda realising the missing zero on the final answer, and corrected it. The main purpose of this episode was to teach learners how to apply simple electric current equation (I=q/t) when given different scenario even though the teacher dominated this process. As mentioned earlier, for lesson 2, everything was done in the laboratory, because the purpose was to expose learners to the practical aspect of the Electricity that Amanda taught in class theoretically. Thus, lesson two, episode three continued with a demonstration of how a simple circuit is connected.

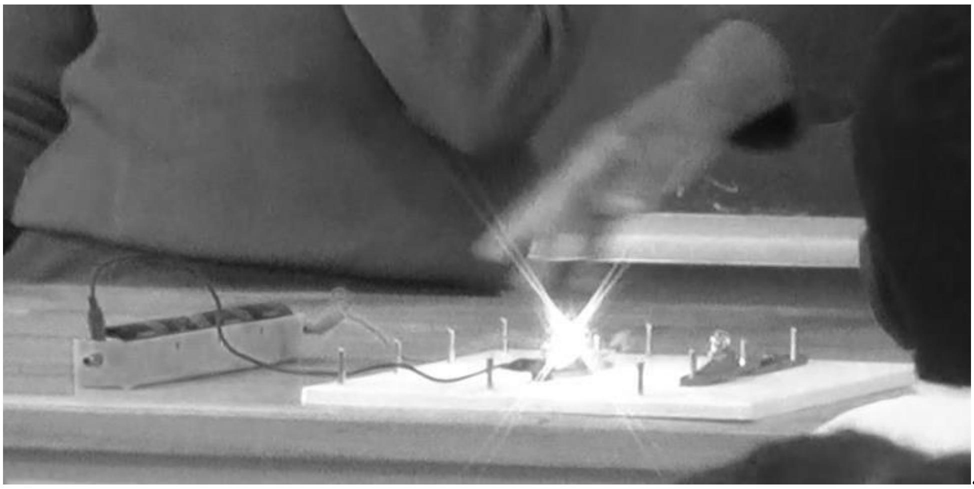
Lesson 2, episode 3

While the Electric circuit practical connections practice is commendable, however, Amanda did not explain how it linked with the electric current calculations above, to develop the scientific story and promote concept continuation for learners‘ meaning-making of science processes. Without taking anything for granted, once again Amanda started by showing learners the components of an electric circuit, followed by demonstration of a simple circuit connection while explaining what she was doing as she connects. This episode was dominated by interactive/authoritative. She then invited a group of four learners to demonstrate how to connect a circuit, while directing them. The demonstrations were further dominated by repetition of concepts explanations, and learners only confirmed teacher‘s talk and questions with one word item, as a way of completing the sentence. This became a pattern in Amanda‘s lessons and she argued for it during VSRI alluding to learners being unresponsive because ―bayesaba (*they are scared*)‖ hence the teacher‘s authoritative approach, which did not seek to develop learners‘ deep scientific understanding. Amanda emphasised on the content and content skills required for the electric circuit demonstrations to be done in this lesson. It was interesting yet concerning to observe that the teacher explained why learners have connected the way they have. The following extract details the laboratory demonstrations episode three of lesson two.

Amanda: We know the instruments to measure current, potential difference. We know how do we connect an ammeter, an ammeter is always connected in which way? [**Learners**: series] In series whereas the voltmeter is connected in…? [**Learners**: parallel].

Amanda: And then if you look at the difference, an ammeter is connected at a point where you want to measure but a voltmeter is connected across two points, that is the difference. Ok any questions? We are going to do practical now but we engage in resistance first so that when we do the practical where we do this connection, like here for circuits connected in series (*using her circuit board on the front bench in Photograph 31 to complete the series connection while learners are seated quietly*)

Photograph 31: Teacher connecting a simple electric circuit in a circuit board



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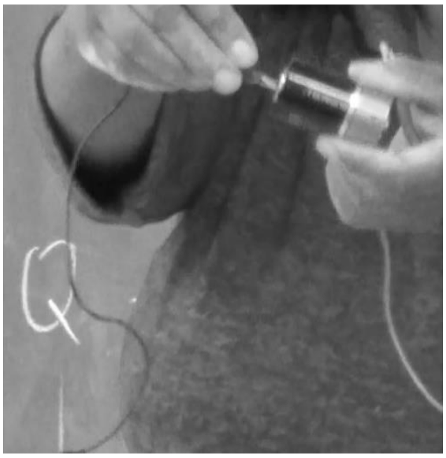
Photograph 32: Light bulb glowing in a complete simple electric circuit

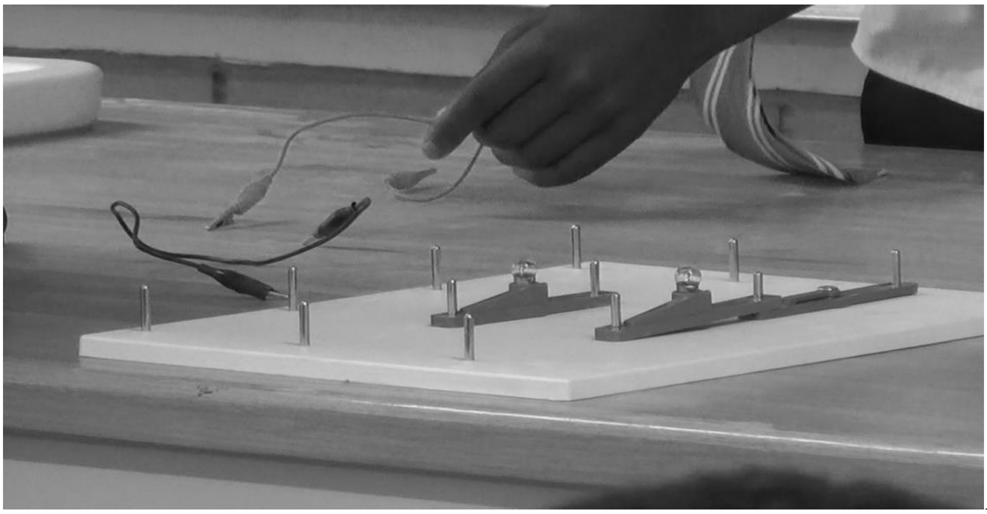
Amanda: So we have got 4 cells (*in the yellow cell holder of Photograph 32*), one bulb connected in series (*Photograph 32 connected by the teacher*). Let me have two boys, come here. (*two boy learners come to the front bench and the teacher gives instructions*) you have to connect in series, so you have one light bulb and four batteries. So this is a connector *(lifting and showing to the class a red wired copper*) it is red, it represents which terminal? A positive terminal. And this one (*black wired copper*) [**Learners:** negative] It represents a negative terminal of the battery. And you know which colour is a positive, which is a negative. This is a positive terminal of a battery you connect it together with this positive terminal (*demonstrating in Photograph 33*). If it‘s a negative you connect it with the negative part of the battery (*demonstrating in Photograph 34*)



Photograph 33: Teacher showing a positive terminal of a cell

Photograph 34: Teacher showing a positive terminal of a cell

Amanda: Ok do this connection (*referring to the called two boy learners in Photograph 35*)



1st step

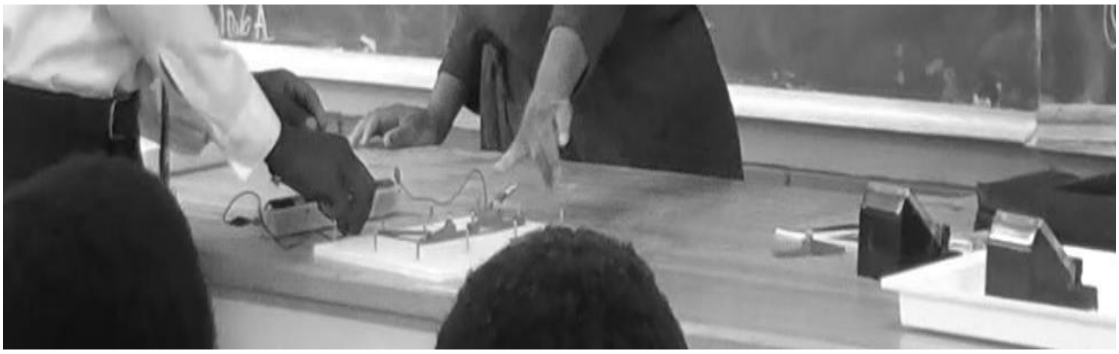
Photograph 35: Learners connecting a simple circuit

Amanda: We want to see whether they have seen what I was doing, just the demonstration.

2nd step

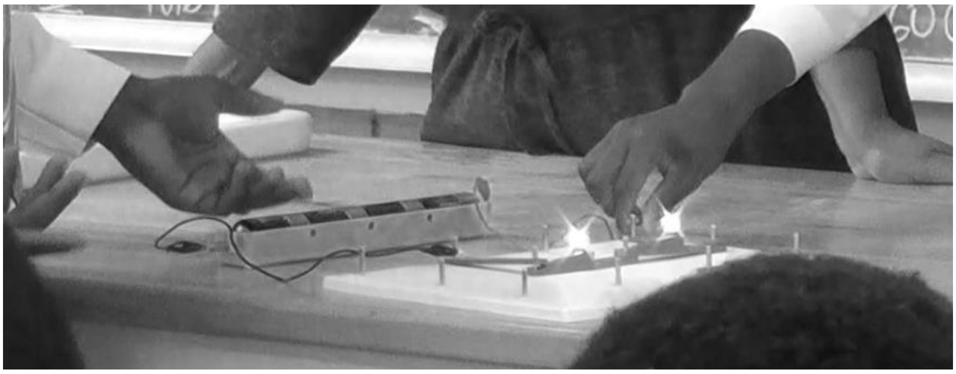
Photograph 36: Light bulb glowing while learners hold connecting wires side-by-side

Amanda: Now it was one bulb you see how it glows, how was the brightness of the bulb? [**Learners**: brighter] It was very, isn‘t it. So these are the connectors (*showing a metal strip to learners in Photograph 37*)



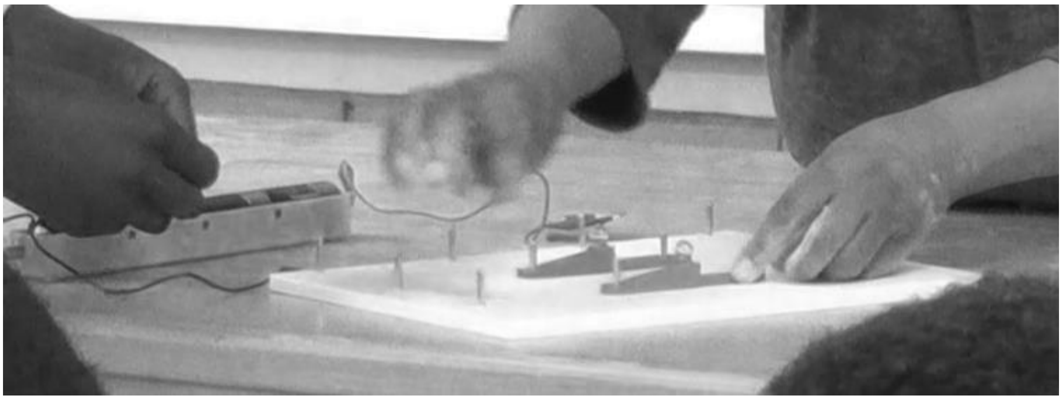
Photograph 37: Teacher pointing learners where they need to connect a light bulb

Amanda: So we want to see if it will glow or not.

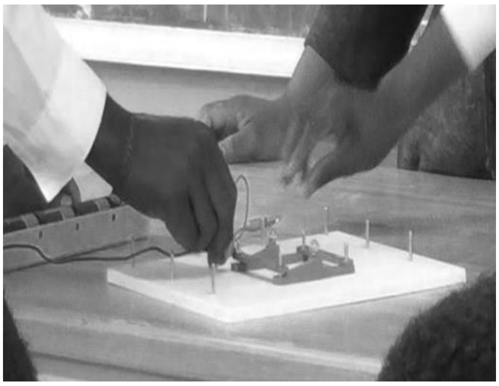
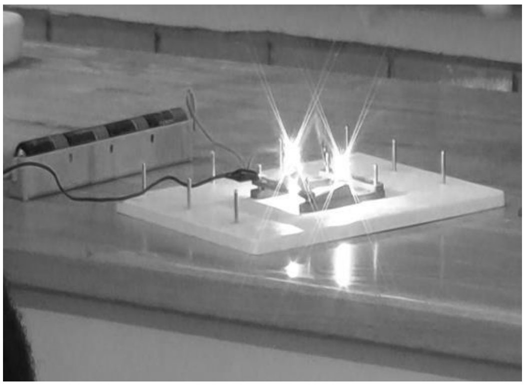


Photograph 38: Two glowing light bulbs connected in series

Amanda: Lets see what is happening when you add more bulbs, what is happening to the current? [**Learners**: it glows] It decreases ok. if you add more bulbs in series, the current will decrease. Now lets connect the bulbs in parallel (*teacher aligns the light bulbs in parallel in Photograph 39*).



Photograph 39: Teacher aligning light bulbs for parallel connection

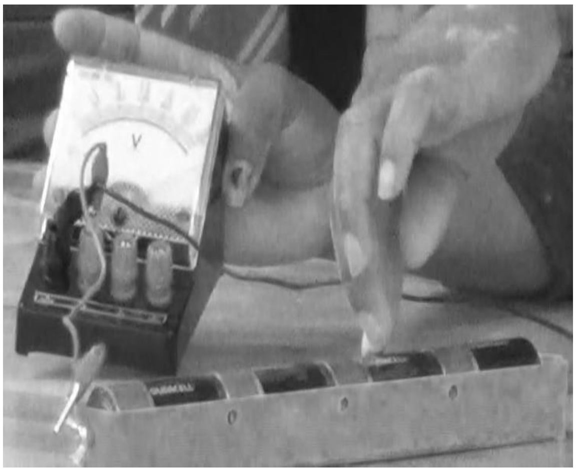
 

Photograph 40: Two light bulbs being connected in parallel and then glowing

Amanda: If you check here, we have been connecting the bulbs in parallel, what about the brightness? It‘s very bright (*saying together with learners*) but when you connect in series, the brightness of the bulb decreases so that is why streets lights are connected in parallel, even our homes when you look at the bulb how is the brightness? it is bright so it is connected in which way… [**Learners**: parallel]

Amanda: in parallel. Clap up your hands (*as they appreciated the two learners who were helping with the demonstration in the front*). Ok what is left now is that we need to use the voltmeter to measure the voltage of this battery, even here we have got the positive as well as negative (*showing the red and black connections in the voltmeter*) so we have to check, who can come, girls now! (*as shown in Photographs 41 & 42*).

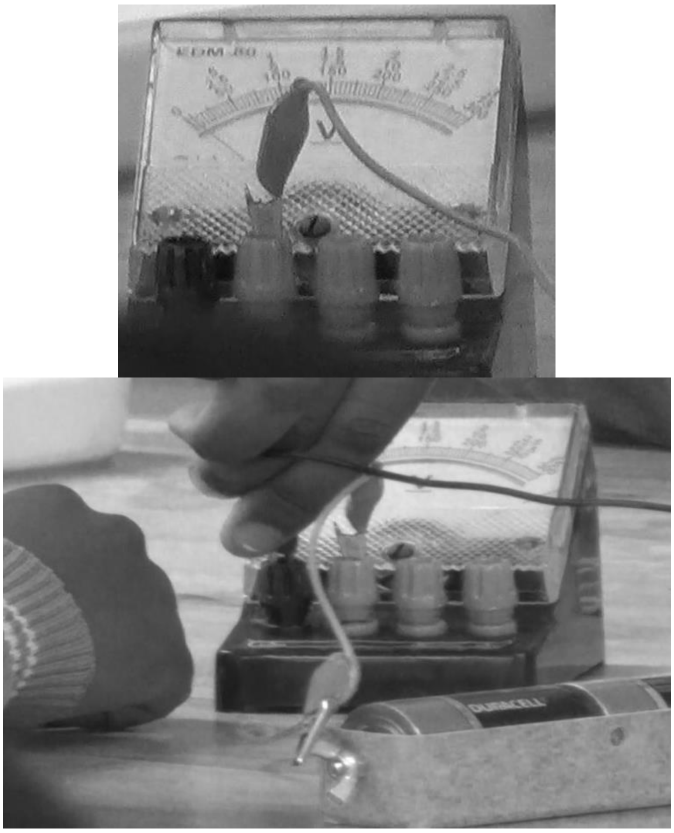
Photographs 41: Teacher showing terminal points for voltmeter to two female learners in front



Photograph 42: learners connecting wires into a voltmeter

Photograph 43: Teacher showing voltmeter reading

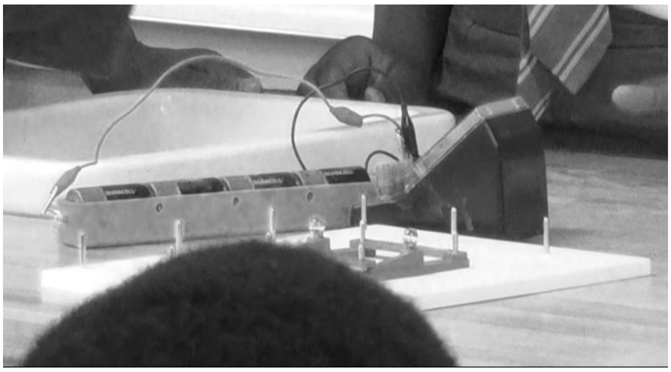
Amanda: Mhhhhhh in fact we want to measure the voltage or the potential difference, so you see this will move (*pointing at the voltmeter needle in Photograph 41*), it will tell you what is the voltage of the battery. Ehhhm 1.5 , 1.5 how much? Its three, three and 1.5 [**Learners**: 4.5] 4.5 and 1.5 [**Learners**: 6] Its 6 volts. And then our voltmeter reads up to 3, you see [**Learners**: yes]



Photograph 44: Voltmeter overshoots

Amanda: You see the voltage is more than 3 (*overshooting in Photograph 44*), you see [**Learners**: no] Show them (*the learners taking the demonstration in Photograph 44 to show learners desk by desk*). If there are learners who still want to see this then you are allowed to use these so that you can check. I am going to write the classwork on the chalkboard. You have seen what is happening? [**Learners**: No]

Amanda: No! The reading is above three so that's why it goes like that. So in other words that is the potential difference of this (pointing at the 6V battery). Now you can even check the ammeter (*the teacher is assisting the two learners to do the battery-ammeter connection in Photograph 45– even though its not clear what exactly is measured*).



Photograph 45: Ammeter-battery direct connection

Amanda: Ok if the current here, its above 5 Amperes, the current of this (*pointing at the connected ammeter in Photograph 45).* Because we are going to do an experiment, in our next period we are going to engage ourselves in doing practical only, ok Grade 10. Because our main focus here was to look at the relationship between potential difference and current, including the resistance because it is very important that you know what is a resistance as I've said that ammeter has got a low resistance whereas a voltmeter has got a high resistance. I have been connecting an ammeter, do you feel the smell? **[Learners**: yes] Because it has got a high current, so we have to check that. Ok let us write our classwork.

In this third episode of lesson two, Amanda included learners to demonstrate their understanding of the process. Initially, the learners stood in front of the class next to the teacher and watched Amanda doing all connections, and then she allowed the learners, two boys and two girls, to do the demonstration of circuit connections. When learners were demonstrating, it was mainly for learners who were sitting in the front rows, because they were not showing other learners in the middle and back rows what they were doing during demonstrations on the front bench table. The demonstrating learners were also not articulating what they were doing, like Amanda showed them, to show the understanding of the process. The teacher did not say anything and left a question about the purpose of the practical if other learners were not included, or the process was not explained to other learners. Amanda repeatedly corrected learners' discourse during the demonstration, for example, underneath Photograph 38 and also ensure that learners used proper scientific discourses underneath Photographs 42 and 43. I observed the misused of scientific tools during the last two female learners' demonstration, that resulted in the needle of the voltmeter immediately overshooting after the connection (Photograph 43).

Amanda tried to figure out what may have gone wrong with the connection, but did not address the scientific error in the connectivity. Instead, she added different cells manually and convinced learners that the voltmeter is not working properly. Without realising the connection mistake, the teacher quickly moved on from this demonstration, resulting to learners‘ immediate _no‘ as a response when Amanda asked them whether they _see‘ what was demonstrated. Another incident occurred when the girls were demonstrating and there was a burning smell coming from the ammeter and this smell seemed to have emanated from the direct battery-ammeter connection where the teacher argues that the smell was due to the high current of the ammeter. Also, the connecting wires were overheating indicating a short circuit connection but interestingly, the teacher rushed through this aspect. Interestingly, during VSRI, Amanda claimed that ―the problem was with these voltmeters, they‘ve got a problem. Even the smell, there was a burning smell. They say these voltmeters have got a problem. I have to use another one…‖ However, after inspecting the voltmeter with the teacher and suggesting if the teacher could use 6 or 9 Volts slots in the instrument instead of 3V, Amanda indicated through VSRI that ‖maybe I can try that‖.

To close her lesson, the teacher gave a classwork and there was complete silence in the classroom as learners copy the classwork questions from the chalkboard to their activity books. Amanda argues during VSRI that the strategy to give learners more activities especially after the lesson content presentation is effective for her and her learners. Once finished with writing classwork questions on the chalkboard, Amanda walks around the classroom checking if all learners are copying down the questions and attempting to answer them. Learners did not complete this task and it was carried over as homework. Therefore, this activity was attended to in the subsequent lesson 3.

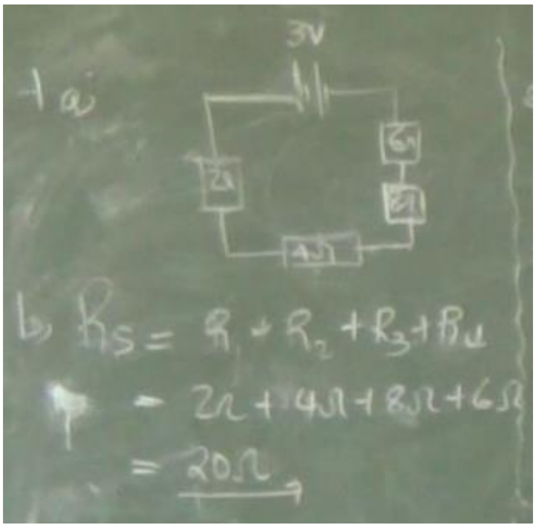
6.2.3. Lesson 3: Teaching Series and Parallel circuit connections through classroom activities

This lesson was dominated by calculations and Amanda‘s focused on analysing resistors connected in series and also connected in parallel. She further explained the concept of resistors connected in series and involved learners during the lesson. The teacher led learners in a step by step process with illustrations on the chalkboard about how resistors connected in series look like. The characteristics of a series circuit of resistors was demonstrated and drawn on the chalkboard and continuously referred to in the lesson. These components were then brought together in forming a drawn simple electric circuit. Learners‘ prior knowledge was triggered throughout the lesson. The lesson was also characterized by various analogical link-making strategies and also led learners through a sequence of instructional questions and answers. In terms of the content taught and learnt, the teacher moves between different scales and levels of explanation.

Lesson 3, Episode 1

At the beginning of the lesson, Amanda started by highlighting that the lesson will focus on resistors connection in series and also connected in parallel. Reference was made to the textbook for the activities that were meant for the teaching of resistors connected in series and also connected in parallel which the teacher had asked learners to do individually at home prior this lesson. The focus of Amanda's teaching in this episode was to guide learners on working with scientific ideas while supporting internalisations of the series and parallel resistor connections knowledge and processes. The following extract demonstrates Amanda's pedagogical approach through classroom activities:

> **Amanda**: In our previous lesson we were looking at resistors connected in series and also connected in parallel. So we will see how we do those activities. Activity number 1, a circuit consists of a 3 volt battery, in series we have a resistor 2 Ohms and 4 Ohms, then they say draw a circuit diagram for this circuit (*teacher proceeds to draw the diagram on Photograph 46*), How many resistors were there? [**Learners chorusing:** there were 4] There were 4, the first one was 2 Ohms and then the other one? [**Learners chorusing:** 4] The other one? [**Learners chorusing:** 6] And the last one? [**Learners chorusing:** 8].



Photograph 46: Working with series resistors and resistance

> **Amanda:** Alright, now we know if they are connected in series, it means if I say three volts I mean this one is 1.5 and this one is 1.5 *(pointing at the two cells in Photograph 46)* so its three volts, they say we have to draw a circuit diagram showing this particular information in

series using a circuit diagram so for us series this is number B we are done with the diagram. Do we have any other person with a different diagram? *(no response).* Others they put voltage this side (*pointing to the left*) as long as this is connected circuit series and you know that the voltmeter, if it is a voltmeter it is connected in parallel, now we are looking at the series circuit. (*teacher moves on to b in Photograph 46*) And then the total resistance of the circuit $R_S = R_1 + R_2 + R_3 + R_4$, which is $= 2\Omega + 4\Omega + 6\Omega + 8\Omega$ okay then the total answer is? [**Learners:** 20Ω] 20Ω okay this is the final answer for number one, and then we go to number two. Number two is taken from our textbook let us page, Grade 10 did you do the classwork? [**Learners subtly:** yes], I don't hear you, what are you saying, yes or no? [**Learners loudly:** yes]. Okay we are on page 151 number two, we are given a circuit diagram, and they require us to find what? The voltage across each of the other resistors and B across a battery. Okay anyone wrote this come forward please…(*no learner came through*) What was the problem? Right they are asking if the Voltage across the two ohm resistor is one volt, remember all these they are connected in series, what about the voltage, what do we say when resistors are connected in series, what about the voltage, is the voltage the same or we divide the voltage? We said the voltage is? What is the voltage at resistor number two, that is 2Ω, we are given the voltage which is 1v it means the voltage again is one, okay? It's one volt there.

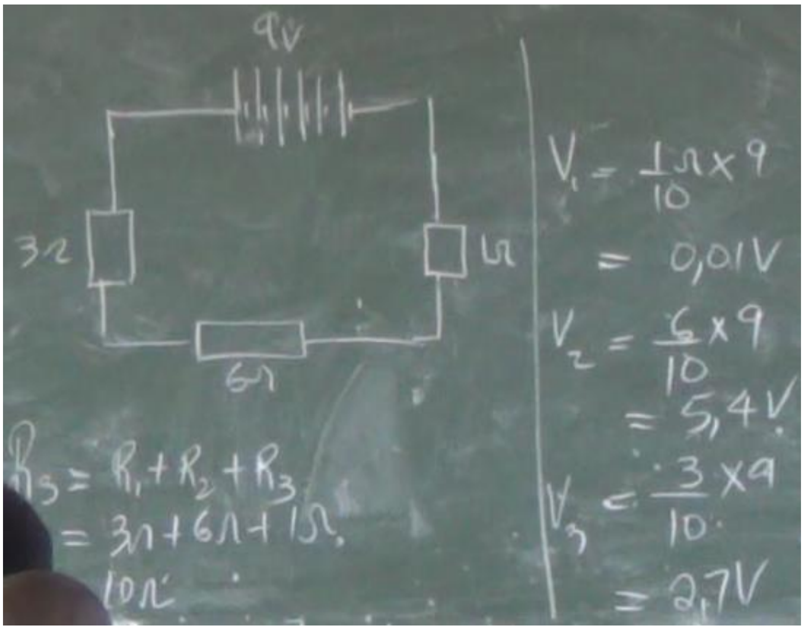
Amanda started the lesson by referring to the previously given task and did all the writing of the corrections. The teacher dominated the classroom talk in a form of feedback authoritative communicative approach through teacher's initiation-response-feedback patterns of discourse. In this episode, Amanda taught some content skills of resistors connected in series through activity-based calculations that were done by the teacher for learners. Amanda used a chalkboard to draw diagrams to help negotiate scientific meanings of the content and demonstrated how learners should draw scientific diagrams for resistors connected in series in Photograph 46 (series circuit connection). Learners were only involved by responding to the number of resistors needed to be drawn in the diagram. Amanda developed a scientific story by making links between modes of representations when linking the diagrammatic representation in Photograph 46 and the symbolic representation underneath the diagram by inferring the resistance calculation to the diagram. Though not explicitly mentioned by the teacher but this scientific story fits within the broader development of a scientific story from the previous lessons' demonstrations of series connections.

Moreover, it was interesting to observe Amanda writing the total resistance for series resistors' equation, substituting the resistance values, and then only asked learners the final answer. However, it was concerning to observe the limited learner involvement, especially when considering that it was the first time learners had to actually calculate total resistance in series connection. After the final answer, Amanda confirmed the answer and quickly moved to the following question. The episode was characterised by Amanda's initiation of a selfconversation through questioning and this was seen as she asked a series of instructional questions that she eventually responded to. The teacher then moved between different scales and levels of explanations after observing that learners did not to know about voltage across resistors. After observing that learners were not responsive to most of her questions, Amanda revised the understanding required for Photograph 46 diagram and then teaches content through another exemplary calculations in episode 2.

Lesson 3, Episode 2

In this episode, Amanda took learners through the step-by-step knowledge skills required to calculate total resistance for resistors connected in series. She taught the scientific knowledge through this episode though learner involvement was still minimal. She moved between different scales and levels of explanations while also making pedagogical links between scientific concepts (resistance and voltage) and their sequencing to develop scientific story and promote concept continuity. The teacher sequenced the content within and across lessons. The following extract demonstrates,

> **Amanda**: okay let me revise this again, let‛s check here again *(pointing to the last diagram drew)* you will be given any scenario it can be a given diagram, let‛s say you are given and then you are required to know, first of all the type of diagram, if you look at this diagram, it shows that the resistors which are connected in series so they follow one another, alright so now you need to find the total resistance of the resistors connected in series. If they are in series what do we do? We said if they are in series we add all the resistance of the resistors. We add all the resistance of the resistors, so here in this second diagram how many resistors do we have? 1, 2, 3 and then we said the formula for calculating resistance of resistors in series we said R_s so Rs means the total resistance of the resistors in series. So now we use the formula $R_1 + R_2$ if they are two, if they are three we said $+ R_3$ and if they are 4 then we can add $+ R_4$. Then we calculate we get this answer, so this answer is for the total resistance of the resistors connected in series. Now the other question says calculate the voltage, now in this circuit diagram you were given the total voltage of this circuit as 9v, do you hear me? It was 9V.



Photograph 47: Series resistors and Voltage across resistors

> **Amanda**: now they require us to calculate now the voltage across this 3Ω, the voltage across this 6Ω resistor, the voltage across this resistor 1Ω how do we do that? Let me start with this one (*pointing to the equation for V_1*) for this one which is 1Ω resistance this is 1Ω resistance this is 1Ω divided by the total resistance which is [**Learners respond:** 10] times the voltage of the circuit so that we will be able to know what is the voltage of this resistor (*pointing to 3Ω*) then we calculate we get this answer (*0.01V*) do you see here? [**Learners respond:** yes]. Again for the second one which is 6Ω, we said 6Ω /10Ω, which is the total resistance of the circuit times the voltage of the circuit (9) that's why we arrive at this answer which is 5.4 so it means this one which is 6Ω is using 5.4V and then we go to the next one which is 3Ω again this is 3Ω / total resistance times the voltage of the circuit then you divide again you come out with what? 2.7, so now it means resistor which is 1Ω is using 0.01V, the one which is 6Ω is using 5,4V the one which is 3Ω is using 2.7V. So if you add they will give you 9.

Amanda reinforced what she taught in the first episode of this lesson. She started by referring to the diagram in Photograph 46 while explaining the content skills for total resistance of resistors in series, including how to calculate this total resistance through the symbolic representation of R_1, R_2, R_3. The teacher talk was dominant during this explanation while learners listened quietly and were often involved to validate the teacher's answers and not necessarily to check or develop their concepts understanding. Moreover, the teacher used meso-scale level links when drawing on resistor and resistance knowledge from the previous lessons, to introduce voltage calculations in series circuits. In her voltage calculation, the teacher did calculation mistake where instead of 9Volts, the teacher calculation on the chalkboard totals to 8.11Volts (see Photograph 47). The mistake emanated from the 1Ω/10 calculation where the final was supposed to be 0.9V instead of 0.01V calculated by learners and written on the chalkboard by the teacher. This was concerning especially when teacher's evaluation of learner responses is taken into consideration. Implications of this practice are that learners might not have been following on the teacher calculation. What was interesting however, was to observe the teacher doing the 1Ω/10 calculations on the chalkboard while explaining, and then she re-explained all the calculation steps, yet the calculation mistake was not picked up instead it was repeated in the re-explanation. Without overlooking the complex process of teaching, this addresses the importance of teacher‘s constant reflection during teaching and learning process.

Lesson 3, Episode 3

To further develop her scientific story, Amanda moved to calculation of resistance in resistors connected parallel in the third episode. The following episode demonstrates how Amanda approached calculations of parallel resistor connections,

> **Amanda:** then we go to number B, Calculate the equivalent resistance for this circuit, leave your answers as a fraction, now how do we calculate the equivalent resistance, let‘s use the formula so we‘ve got (*teacher writes the equation on the board*) $1/R_P = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 = 1/1 + 1/2 + 1/4 + 1/8$ and then we look for our lowest common denominator okay? What was our common denominator? [**Learners:** 6] what about 8? [**Learners:** yes] the nearest one is 8, the lowest common multiple is 8, okay 1 into 8? [**Learners:** 8] 2 into 8? [**Learners:** 4] 4, here? (*pointing at 4*) [**Learners:** 2] here? (*pointing at 8*) [**Learners:** 1] right say 8 and 2, it is 10, 15/8 we get 15/8. We do not want $1/R_P$ but we want R_P so we said =8/15, then you come up with the answer what did you obtain? [**Learners:** 0.5] grade 10 what was the correct answer? [**Learners:** it said in fraction] Yes in fraction, very good so it means we need the answer like this but if we make it into the first decimal comma it is 0.53 and then there is it, how many obtained it correct, how many obtained it correct? How many? (*no response*) and then we are done now, do corrections, do corrections and then I‘m going to give you another task.

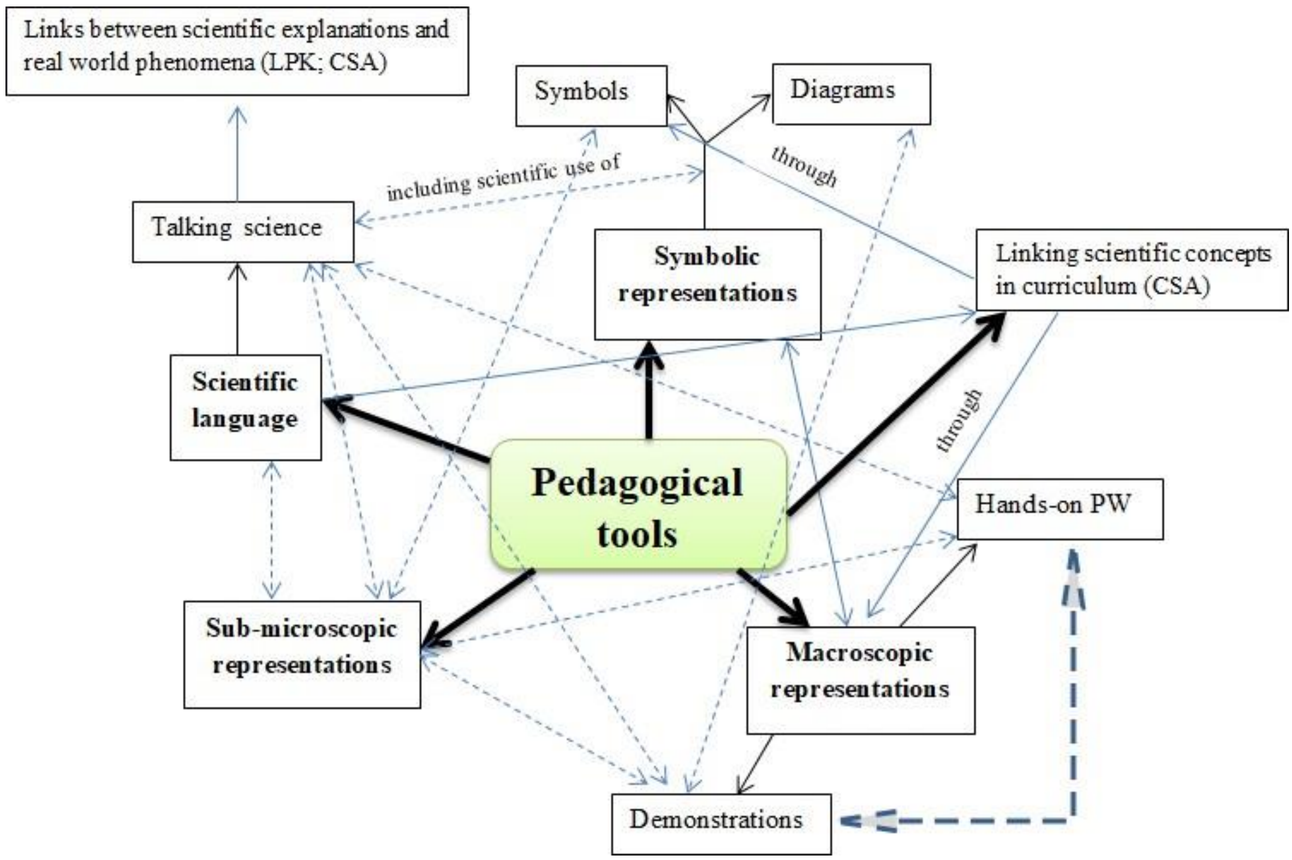
Learners were introduced into total resistance in parallel resistor connections and how to calculate it. As argued during VSRI that ―I was talking to myself. When I checked their exercises they were correct but they do not want to raise their hands. Like I said that they are scared‖ (Amanda), and this served as the reason for the teacher to do the task for learners instead of giving the responsibility to learners. Also, the teacher modelled how to interpret and solve parallel resistor problems. Teacher talk and action dominated from reading of the question, to its analysis, giving the equation to be used, and the substitution. In this episode, Amanda led learners through a series of confirmatory questions in an attempt to make micro level links by drawing from learner prior knowledge (LPK) of the two previous episodes of the current lesson and extend this knowledge base. A concerning practice was observed when the teacher asked about the lowest common denominator (LCD) and learners gave 6 as an answer and then the teacher asked learners about 8 and alludes that 8 is the nearest it was concerning because it meant that learners were unaware of LCD or they had a misconception about LCD yet the teacher did not explain what is known as LCD. Implications are that learners may continue with their held misconception about LCD even after this teaching. The nearest part was left unattended by the teacher, even though learners had incorrectly given a lowest common denominator. Moreover, similar to episode 5 of Amanda's lesson 1, where the teacher skipped the cross-multiplication step in calculation procedures, Amanda skipped or did not mention the inversion step for 15/8 to 8/15 for the final answer to $R_{P.}$ And implications are that, learners may not know how to do cross-multiplication. The following chapter presents and analyses data from teacher Sipho's classroom practices.

6.3. Chapter summary

In this chapter, I presented, explained, and analysed Amanda's enacted pedagogical content knowledge of Electricity topic and her pedagogical reasoning that influenced her observed pedagogical practices of Electricity topic. Classroom observation and video stimulated recall interview data sets informed the analysis in this chapter. Emerging from the analysis, Amanda's teaching was largely subject-matter centred. The teacher made use of pedagogical tools such as symbolic including diagrammatic representations; macroscopic representations which included teacher demonstrations and hands-on learner demonstrations; references were also made to sub-microscopic behaviour of concepts taught; and the scientific language of talking about Electricity concepts and processes. These tools were not linearly used but there was back-and-forth in their usage. Of these tools, symbolic representations in the form of symbols and diagrams were dominant in the observed lessons while Electricity concepts and processes were barely represented at sub-microscopic levels of representation. Interestingly, scientific language was encouraged within and across lessons in enculturating learners into science discourse while the teacher develops and maintains a coherent scientific story. Figure 9 below represents the complex nature of pedagogical tools used and the interrelationship between these tools in teacher Amanda's classroom.

Figure 9

Teacher Amanda's pedagogical tools used in the Electricity lessons



While making links between the various pedagogical tools used, the teacher also made content and pedagogical knowledge links across grades, across lessons, and from within lessons in her attempt to develop a coherent scientific story for Electricity topic. These links were justified in VSRI as important for formation and continuity of concepts within Electricity topic and across curricular (CSA), where the teacher would constantly remind learners and draw from their prior knowledge (LPK) while also helping them navigate through what is usually difficult to learn about Electricity topic (WDT). This was the reasoned important conceptual teaching strategies (CTS) and the possible factors that influence it from the teacher's perspective.

CHAPTER 7

Sipho's tsPCK to support Electricity knowledge building: Data Analysis

7.1. Introduction

The current chapter focuses on teacher Sipho‘s observed lessons of Electricity topic in Grade 10 physical science classrooms**.** This pedagogical analysis presents what the teacher said and did; the development and facilitation of concept formations and understanding, the pacing and sequencing of the content during each lesson. The analysis of the classroom video recordings and video stimulated recall interview were done using the topic specific Pedagogical Content Knowledge, pedagogical link-making, and communicative approaches. The following discussion details Sipho‘s classroom practices and I begin the discussion with the overview of the three observed lessons and subsequently detail each lesson.

7.2. Sipho's classroom practices: Lesson observation narratives

Sipho was observed teaching three lessons, and a total of six teaching episodes were identified and analysed in the following sections. Sipho‘s first lesson was an introduction to electric circuits focusing on Ohm‘s Law, and the potential difference was taught first, followed by electric current, and then resistance. The Ohm‘s Law components (V, I, R) were then represented diagrammatically through a simple electric circuit on the chalkboard. The potential difference (v), current (I), and resistance (R) were explained independently and the teacher drew from learner‘s prior knowledge of electrostatics, which was taught prior to this lesson. To teach the potential difference, electric current and resistance, Sipho used calculations which focussed on the symbolic representation and the manipulation of equations. Sipho‘s first lesson took 35 minutes, 21 seconds from introduction till the end of lesson. In the second lesson, Sipho focussed on series and parallel circuits and used diagrammatic representations which were drawn on the chalkboard and linked with the symbolic representations (calculations) on electric current, potential difference, total resistance done for both series and parallel circuits. The second lesson lasted for 32 minutes, 23 seconds. Furthermore, classroom activities were used in the third lesson for the calculations of electric current, resistance, and potential difference for resistors connected in series and resistors connected in parallel electric circuits. This lesson took 40 minutes, 06 seconds. All the observed lessons including drawn electric circuit demonstrations were conducted in the classroom. For all the observed lessons, there were approximately 35 to 40 learners per the observed lesson. The following section presents the first observed lesson.

7.2.1. Lesson 1: Introduction to electric circuits

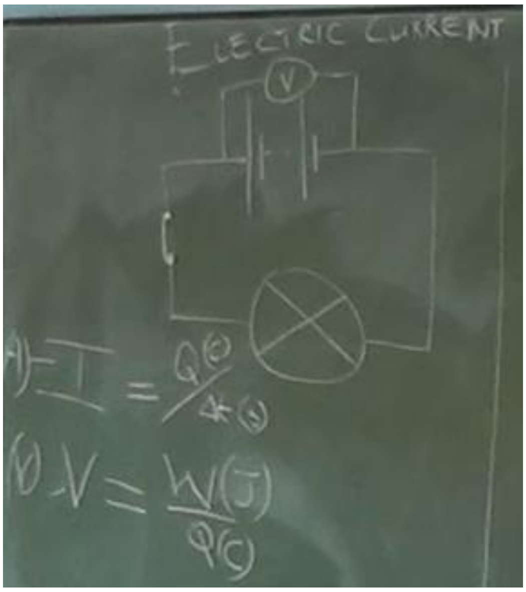
Lesson 1, Episode 1

As mentioned earlier, this lesson took place in the classroom context and Sipho introduced the idea of electric circuits which came immediately after a lesson on electrostatics. He gave learners the examination guidelines[32] and referred to the Electricity topic section of the guideline, drawing learners‘ attention to what was examinable under this topic from the guideline. It was evident from the beginning of the lessons that Sipho‘s teaching approach was influenced by the use of the examination guideline during the lessons, considering the constant reference (as noted in different extracts) that further influenced learners‘ approaches to learning the topic. The teacher confirmed this preference in the VSRI discussion that the examination guideline is better than textbooks or any other teaching and learning material, because ―*…it has all the definitions and then they (learners) must know them exactly the same as written in the guideline. Which means everything that is going to be asked during the exam is here (exam guideline) it‘s a scope…*‖ (Sipho). The following episode illustrates how Sipho introduced the electric circuit lesson,

> **Sipho**: The business of the day, we are looking at electric circuits, isn‘t it? When we talk of electric circuits we talk of ehhmm, a simple electric circuit, we said it must consist of any power source, any power source, and we said any power source can be cells or battery. So this is a power source *(teacher drawing a battery‘s symbol for electric circuits in Photograph 48)*. What other power sources do we have except batteries? [**Learners** (chorusing): Bulb]. Power source! What can you use instead of batteries? [**Learners**: Generator]. And [**Learners**: Solar]. That is correct… Previously we talked of the electrostatics, we said we look at the charges that are at rest. So electrostatics, charges are at rest, but now if we talk of electric current, we talk of the charges that are? [**Learners**: moving]. That are flowing, so now we talk of charges that are flowing. Then a voltmeter, what is measured by the voltmeter? [**Learners** (chorusing): potential difference]. Now we talk of the potential difference that causes charges to flow. And then how do we define potential difference? [**Learner**: Energy transfer per unit charge]. Potential difference is energy transfer per unit charge. Now when

[32] Examination guidelines is a Curriculum and Assessment Policy Statement‘s (CAPS) aligned document which is given to teachers with the aim to ―assist teachers to adequately prepare learners for the examinations‖ (DBE, 2021, p. 3). See Appendix 14 for the examination guidelines section used by Sipho during the teaching of the topic of Electricity.

there is potential difference, there will be flow of this charge (*pointing at the circuit diagram in Photograph 48?*) which means we now talk of electric current. What is electric current? (*no response as learners page through their textbooks*) according to your exam guideline. This is a recap. [**Learner**: Is the rate of flow of charge]. Is a rate, *uma sithi kwa*-science *(*when we say in science*)*, _rate‘, we mean to say per time, so it‘s a rate of flow of charges, so this is what we talked about. This is a definition of electric current and also this is an equation for electric current (*pointing at the, I=Q/t, equation*). And then we said the current is measured in amperes. What is the definition of the resistance according to your exam guideline?... the symbol for resistance is capital letter R and we say it‘s a ratio of potential difference to the current so we are going to have the formula that says R=V/I…we said I (*from R=V/I*) is electric current of which is measured in? [**Learners**: Coulombs]. Current! [**Learners chorusing**: Ammeter]. It‘s measured in Amperes, an ammeter is an instrument. The SI Unit for current is amperes (*the V and I units were summarised as (V) and (A) on the chalkboard in Photograph 49*).



Photograph 48: Simple Electric Circuit

Sipho introduced the focus of the lesson, which is a Big idea on electric circuit and structured the topic in his introduction. Curricular saliency (SCA) was further used to explain the meaning of concepts and link the current lesson with the previous lessons on electrostatics, which Scott et al. (2011) calls meso scale level of link-making to promote continuity and develop the scientific story. To present the object of the lesson, Sipho wrote _electric current‘[33] on the chalkboard as the focused topic (see Photograph 48), while he mentioned that the lesson focuses on _electric circuits‘. This was a disconnection between what was written on the chalkboard, spoken by a teacher, and drawn on the chalkboard (Photograph

[33] This could have been an honest mistake from the teacher or it could be that the teacher is un/consciously _current minded‘ as suggested by Bradley, Khulu et al. (2019) that teachers tend to be more _current minded‘ when dealing with electric circuits.

48), as Sipho continued to talk about power source in an electric circuit, and drew a battery symbol with the voltmeter sign. There was incoherence in teacher‘s discourse, lesson intention, and symbolic representation on the board, which is a concern in a classroom that tries to develop scientific knowledge. Interestingly, while he drew a light bulb in the Photograph 48 electric circuit, he asked, _*what other power sources do we have except batteries?‘* and learners answered _*bulb*‘ which was a wrong answer and Sipho simplified the question to _*what can you use instead of batteries*?‘ and learners gave different types of power sources including generator and solar which were then confirmed by the teacher as correct. As the lesson progressed, I noticed the discontinuation between the discussion of power source and the charges at rest the teacher referred to after power source. This discontinuation is concerning, especially when considering a development of a coherent scientific story through aligning what the teacher says (teacher talk) and what he does (writing on the chalkboard).

Sipho‘s pace of the lesson was fast from the introduction of the lesson, as he talked about different concepts including learners to complete the sentences through initiation-response-evaluation (IRE) pattern. While it could be perceived as another strategy to evaluate learners‘ understanding or lack thereof of the science concepts, as he noticed some learners‘ wrong answers, Sipho did not take the opportunity to explicitly explain the misunderstood responses. Instead, the teacher instructed and encouraged learners to page through the textbook for answers, which is evaluative authoritative approach because the focus was on getting the correct answer than understanding the meaning of the concepts. This was noticed when learners could not define the concept of electric current when Sipho asked them instead they were paging through the examination guideline looking for an answer. It was clear from this practice that learners did not yet build sufficient science knowledge, if any; because the teacher‘s conceptual teaching strategy (CTS) suggested lack of confidence to teach the content for conceptual understanding. Sipho constantly referred learners to the examination guideline to memorise the information for regurgitation, as noted in the classroom practice and confirmed in the VSRI responses. Even when Sipho talked about the concept of electrostatics that was already taught, he continued to use the interactive yet authoritative approach and concentrated on teaching pieces of information.

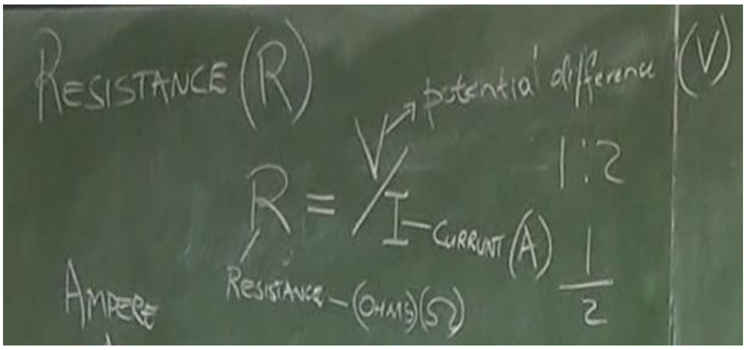
Sipho continued with the lesson and re- explained the link between pd and charge flow, which led to the idea of electric current. There was a suggestion for a causality effect[34] between pd and charge flow even though the nature of this causality was not explained. It was interesting to observe Sipho not taking the meaning of ‗rate' for granted during the lesson, emphasising the ways of talking and understanding a scientific concepts in a science context. This was the way to build scientific knowledge by explicitly explaining the concept within the science context, for learners to understand that the concept ‗rate' is used in other context or subjects. Unsurprisingly in the rural context, Sipho used the chalkboard to present the definitions of potential difference (V=W/Q) and electric current (I=Q/t) symbolically (see Photograph 49), which linked with the different representations of content (diagrammatic to defining scientifically - SP-DS, and to symbolic representation) to develop a scientific story and support concept continuation (Mavhunga, 2012; Rollnick & Mavhunga, 2014; Scott et al., 2011). Without overlooking Sipho's pedagogical practice, it was concerning that the teaching of important concepts and information centred on examination guide without effective explanation from the teacher. Given this approach, it is not easy to confidently say learners built scientific knowledge and understood the interrelationship between different concepts, especially if their short answers are seriously considered.

I further noticed that the teacher did not make links between the potential difference (V=W/Q) and electric current (I=Q/t) equations written on the chalkboard and the electric circuit drawn in Photograph 48. Instead, Sipho used the electric circuit diagram when recapping the components of electric circuits and technically explained the concepts of potential difference and electric current which were then linked to their symbolic representations (equations). Similarly, after electric current equation, Sipho informed learners that he was now focussing on resistance, which shape incoherence and might be confusing to the learners. The observed constant switch from concept to concept with little attention to building a coherent scientific story through linking scientific concepts and including learners to the teaching and learning process, building from their prior knowledge, encourages memorisation. For the focus on resistance, Sipho asked learners to provide the definition of resistance from the exam guideline, which he later defined as ―*anything that opposes flow of charges.*‖ Again this definition was represented symbolically as R=V/I (Photograph 49), and Sipho asked learners about the SI Units (International System of Units) of electric current and

[34] Stationary charges being given energy by potential difference resulting to the flow of charges which is then termed as electric current, according to Sipho's teaching.

learners‘ response was Coulombs, which was incorrect and then uttered _*ammeter*‘ which was also incorrect. It is this learners‘ guessing game which suggests that they have not made links between different concepts and their scientific meaning has not been built yet, and the teacher appeared to overlook this. Then, Sipho gave the correct SI Units (Amperes) while also noticing learners‘ misconceptions about the ammeter mentioned that _*an ammeter is an instrument‘*. He then differentiated between the SI unit and the instrument, in his confrontation of the observed misconception. In the VSRI, Sipho said he emphasised (CSA) the function of an ammeter for learners to understand _*that there is an instrument and there is an SI Unit, so that one is the instrument the one that is used to measure current and amperes is an SI Unit*‘ (Sipho).

Due to the observed misconception (LPK) regarding electric current‘s SI Unit, the teacher emphasised the idea of ampere as the SI unit and wrote the individual SI Units on the resistance equation on the chalkboard (Photograph 49). Even writing information on the chalkboard is important, especially if the chalkboard is the only teaching tool, teacher‘s content knowledge, effective explanations, and explicit link making of different concepts is important to support the knowledge building. Sipho‘s communicative approach was dominantly evaluative and confirmatory authoritative because he only wanted learners to give information that was in the examination guide. This is teaching for assessment and /or examination and disregarding connecting the current topic with the future topic, to show learners the topic and concepts continuation.



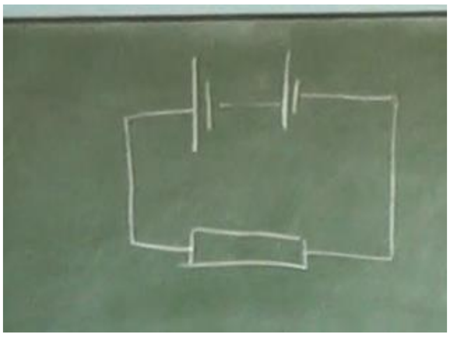
Photograph 49: Resistance equation with SI units (Ohm‘s Law equation)

This episode has demonstrated an influence of the examination guideline in Siphos‘ teaching approach, especially on the question and answer approach, and concepts taught through equations (symbolic representations). The teacher‘s approach to the topic and concepts raised questions about the nature of his science content knowledge, because there was no observed detailed explanation of concepts and effective use of learners' prior knowledge. It appeared like learners were familiar with this teaching approach, and confidently paged through the examination guide for answers, without attempting to think about the process. Sipho constantly listed concepts and mostly explained them individually without showing their interrelationship, for learners to see the continuation and how they develop a scientific story. Sipho continues with the resistance explanation and demonstration in episode 2.

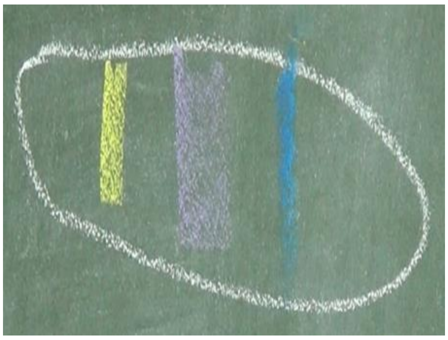
Lesson 1, Episode 2

After the definition of resistance, its symbolic representation and links to potential difference and electric current (R=V/I), Sipho focused on resistance in relation to electric current (charge flow) in this episode. An analogy was used to describe the resistance and electric current relationship, including drawings on the chalkboard that were used to explain the connection of a resistor in an electric circuit (Photograph 50) and how resistors look like (Photograph 51). Factors that affect resistance of materials were also explained by the teacher. Below is the teacher talk:

> **Sipho**: Voltmeter is always connected in parallel… Voltmeter has high resistance, you can't connect it in series because which means it will block the current since *ine*-resistance *enkulu* (it has bigger resistance) it will block the current. Remember I'm trying to say that resistance opposes the flow of charges so now *uma ngabe une resistor enkulu* (when you have a bigger resistor) which means definitely there will be no flow of charges, you see. I can't pass here (pointing in between learners) because there is no space, I mean you have two big desks but if the desks were small I could pass through it so i-current *ayikwazi ukuhamba lapho okune-resistor enkulu* (the current does not move where there is a bigger resistor). Given a circuit, when we talk of resistor, when we are given a circuit like this (*draws an electric circuit in Photograph 50 below*):



Photograph 50: Simple Electric Circuit

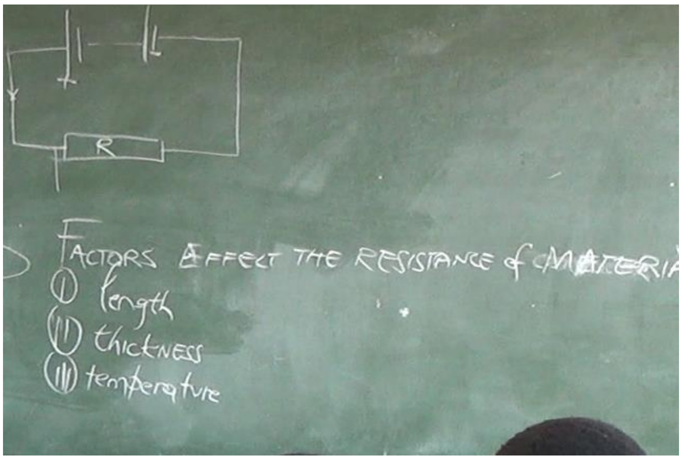


Photograph 51: Colour coded resistor drawn on the chalkboard

> **Sipho:** You know here you have a battery so if we put a resistor here, remember in Grade 9 we talk of resistors they are colour coded, do you remember? [**Learners**: Yes]. If *sikhuluma nge-resistor sikhuluma ngento ethi mayibe nje* (If we talk about a resistor, we are talking about something like this) then it has colours which represent the Ohmic of that resistor (as

drawn in Photograph 51), but in Grade 9 you did these resistors. Ok do you still remember this? [**Learners**: Yes].

Sipho: Then a resistor, we say this is resistance (pointing at the resistor symbol in the drawn circuit diagram) and then a device it‘s a resistor… if you want to trace the charges you start from the positive to the negative that is conventional current, current flow from the positive terminal to the negative terminal… Remember that previously we also talked of emf so that will cause charges to flow… Like for instance, in wiring our houses like here in the class, they used copper wires those brown ones, angisho (isn‘t it)? [**Learners**: Yes]. Remember I said emf, if you have a battery *ibhalwe* (written) 12volts, what does it mean, it means that volts is an emf. At this grade we look at the emf equals to potential difference, which means we ignore the resistance of the wire, it is there we ignore it. So, now in this resistor, we have factors that effect the resistance of a material (*the teacher then writes down these factors and explained these individually in Photograph 52*).



Photograph 52 Factors affecting resistance of materials

It was interesting, even though unsurprising, to observe generally, and particularly in this episode that learners have agreed to know and understand everything the teacher asked them which is seen through the _yes‘ confirmatory responses from learners. Irrespective of such confirmation from the learners, Sipho quickly evaluate learners‘ answers and moved on to the information he wanted to cover, without allowing learners‘ engagement to discuss the confirmed concepts. This pedagogical approach is detrimental to the meaningful acquisition of knowledge, especially if some information was already taught to tap into the learners‘ prior knowledge (LPK) through interactive/dialogic communicative approach and work on different scientific point of views. However, Sipho diagrammatically demonstrated the connection of an ammeter and voltmeter in electric circuits, and focused on the voltmeter and extended its description in electric circuit connection to the concept of resistance. During the process of making links between different scales and levels of explanation, Sipho presented all three levels of representations at once to the learners. He combined the sub-microscopic, macroscopic, and symbolic levels during the explanation, trying to simplify and bring science to life by connecting it with the classroom environment and society. Scott et al. (2011) caution that when the teacher moves between the phenomenological, theoretical, and symbolic scales in developing an explanation, should be made explicit to prevent students' confusion and being lost somewhere between the three levels. Chandrasegaran et al. (2008, p. 294) states that ―the acquisition of knowledge by students without a clear understanding may be attributed to the confusion caused in having to deal simultaneously with macroscopic, submicroscopic and symbolic worlds of science‖.

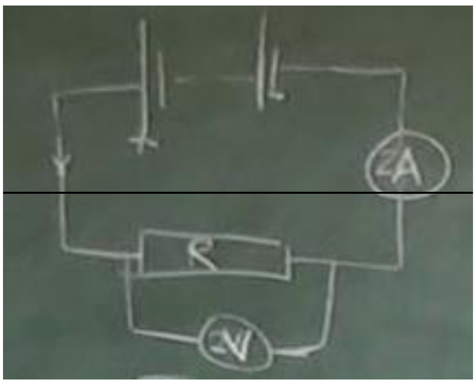
The teacher's use of an analogy of desks size and arrangements in class, which indicated the use everyday and familiar scenario to demonstrate a scientific process was to help learners ―*…visualize the relationship between resistance and current in a circuit*‖, Sipho expressed during VSRI. The teacher used code-switching between IsiZulu and English languages to clarify the meaning and use of the concepts of resistor, resistance and electric current for learners' understanding of how these concepts work together relationally. Sipho justified his code-switching practices during semi-structured interviews that he ―*switch if there are clarities that needs to be done*‖ to enable access to scientific skills and processes. However, from the extract, the teacher did not use code-switching for clarification but for the explanation of the relation of the flow of charges and resistance, and when demonstrating a resistor on the chalkboard in Photograph 51.

Moreover, Sipho was observed making constant content connections between current topic and previous grade's work which was to show learners the relationship and concept continuation at macro time scale levels (Scott et al., 2011), so they see the interconnections between different concepts in the Electricity topic curriculum (CSA). In his attempt to link previous grades' concepts and current topic, Sipho drew the colour coded resistor in Photograph 51. The drawing was made on the chalkboard because Sipho indicated during VSRI and semi-structured interview that he does not have science materials (laboratory equipment) hence he uses the chalkboard for learners to visualize taught content. Also, Sipho relied on the use of micro time scales when reminding learners about the concept of energy source which powers the flow of charges with the specific emphasis to emf. This concept was taught earlier in the same lesson and the teacher drew from it to link with the electric current explanation for concept continuity and progression.

Furthermore, the move between teacher talk, analogical link-making and the different diagrammatic, and symbolic representations on the chalkboard was to assist learners to hear, visualise, and connect the different concepts and their processes, even though the chalkboard does not show the current flow from the positive terminal to the negative terminal for Photograph 50 but is indicated in Photograph 52 though with one arrow between the positive terminal of the batter and the resistor. I noticed a disjuncture when the teacher pointed at a resistor symbol in Photograph 50 and the resistor in Photograph 51 referring to a _device', while both pictures only showed resistors, hence, the link between the two Photographs (50 and 51) remained unclear from the teacher's explanation. At this point the teacher had not differentiated between a resistor and resistance to prevent learners' misconceptions, considering the possibility for confusion about what they get when calculating for R through the given equation: R=V/I (whether resistance or resistor). The reliant on the examination guide, rushed explanations and interlinks between concepts and procedures suggest that the teacher had limited subject matter content, because the explanation of science concepts was done dominantly through the examination guide with limited opportunities for learner engagements. Sipho included learners to passively confirm teacher's scientific statements and complete evaluative answers, which is dominantly authoritative communicative approach and followed the IRE pattern. Sipho concluded this episode by writing the three factors on the chalkboard (Photograph 52) and explained them. After this explanation, the teacher summarises the content of the lesson by giving an exemplary activity which he eventually solved for learners. The following episode demonstrates.

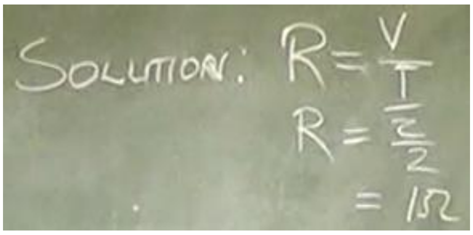
Lesson 1, Episode 3

From the explanation of factors that affects the resistance of the material, Sipho extended the explanations to Ohm's Law mathematically and explained that symbolically resistance is equal to potential difference over current (R=V/I). The following extract demonstrates,



Photograph 53: Simple Electric Circuit

Sipho: Now consider the circuit diagram, calculate resistance, R. We are given 2volts, what is 2volts that is potential difference? What is measured in volts is potential difference and then also here we have an ammeter that reads 2amps, what is this? [**Learners**: Current] It‘s current and then this is what we want R, R is equal to unknown. Remember we said emf at this grade is the same as potential difference but the definition of potential difference that is. It is work done per unit charge in the source if its emf, you add in the source if it is emf but then we take it equal at this grade. And then the other formula is this one, R=V/I in electric circuit these are the formulae we have done so far. Now you chose the correct formula among those ones? (asks the question as he writes _solution‘ on the chalkboard). R is equal to V over I (R=V/I). Do we have R, no its what we are looking for, what is V? [**Learners**: 2] Its 2volts and then what is current? [**Learners**: 2] It‘s 2 amperes then the resistor of this one is one Ohm.



Photograph 54: Resistance solution by the teacher

Sipho: Let‘s go back to the formula, looking at the current versus the resistor. If the current is 2 amperes, the resistor is 2 in that case. Then if you look at this the resistor, *uma ngabe inkulu i-resistor* (when the resistor is big) the current becomes low. Resistor it oppose the flow of charges, so which means if the resistor is big then the current is going to be smaller. The greater the resistance the smaller the current, that‘s an inverse.

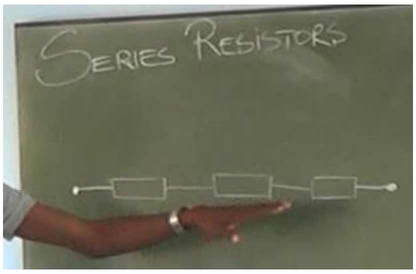
The teacher brought the potential difference and electric current together in a symbolic representation in relation to resistance, and representations (REP) are important to visualise the concepts that are taught in class. The three concepts were represented diagrammatically in Photograph 53 and then linked through symbolic representation in Photograph 54. Though Sipho did the classwork activity for the learners, but through this activity, the teacher connected theory and practice by using the diagram in Photograph 53. He did this to re-explain and emphasise the definition of potential difference, the role of a resistor in an electric circuit, and by referring to curricular saliency issues of emf equated to potential difference for the purpose of Grade 10 teaching and learning. Sipho further explained an inverse relation between current and resistance while drawing inferences on the solution in Photograph 54 on the chalkboard. These concepts were re-explained and emphasised because of their difficulty to comprehend and the possible misconceptions instigating by the concepts. In the VSRI, Sipho explained the focus of the episode, ―…*to help learners see how they were supposed to do the activities*‖ (Sipho argued during VSRI), which shaped the non-interactive and authoritative communicative approach in an effort to _show‘ learners the scientific procedures. Added to this communicative approach, Sipho asked questions and provided solutions without waiting for learners' responses and ideas. For example, after writing the following equations on the chalkboard; $I=Q/\Delta t$ and $V=W/Q$, and $R=V/I$ the teacher asked learners to choose an equation to be used in this classwork activity and immediately wrote *R=V/I* for solution. Additionally, I also noted an unattended mistake by Sipho when he said —*if the current is 2 amperes the resistor is 2 in that case*‖, yet from the performed calculation, electric current was 2 Amps giving 1Ω for the resistance with the conditional 2volts of potential difference.‖ While this might have been the teacher's honest mistake, considering the lack of corrections above when learners did not use the correct science discourses, for example, teacher asked: *what is V? [**Learners**: 2]*, and teacher continues*: Its 2 Volts and then what is current? [**Learners**: 2]* and teacher corrected again: *Its 2 Amperes*. The teacher-learner exchange appears to highlight the teacher's limited pedagogical strategies for ensuring correct scientific discourse of talking about values and units of scientific concepts. The following section presents the second observed lesson where the homework was explained before discussing the contents of the lesson.

7.2.2. Lesson 2: Conceptual understanding of series and parallel circuits

Lesson 2, Episode 1

This lesson focused on resistors in series and parallel circuit connections and lasted for 32 minutes, 23 seconds. However, the teacher begins the lesson by recapping on the previous lesson's content through answering the ‗classwork activity' that was given to the learners on the previous day. The classwork activity required learners to recall what the teacher had taught in the previous lesson. In answering the activity, Sipho modelled how mathematical problem solving should be approached by writing ‗DATA' first on the chalkboard, which highlighted what was given in the question and what was not provided (to be calculated). Sipho reasoned this teaching strategy during the VSRI that the written DATA on the chalkboard was to help learners —*because they are still new to calculations…so it can help them to pick the right formula and then they substitute*‖. In this introductory section of the lesson, Sipho facilitated proceduralisation of learners' scientific processes for mathematical problem solving and wrote R=V/I equation and did the introduced substitution for the learners. I noticed that he verbally performed cross-multiplication step leading to the final answer without writing the step on the chalkboard for learners to copy, given that they were watching him talking. Following the mathematical problem solving, Sipho introduces the focus of the present lesson by foregrounding the examination requirements, where combined resistors in series were the focus. In this lesson, Sipho continued to use the examination guideline to sequence and pace the lesson. The extract below represents Sipho‘s engagement with the series circuit connections,

Sipho: The next thing according to our exam guidelines, we now have to look at the combined resistors… now we have to look at series… [**Learners completing teacher sentence**: Circuit]. **Sipho**: …resistors, series resistors… So, resistors in series are on page 15 of your exam guideline. So if we have resistors that are in series, this is a symbol for a resistor (*teacher drawing three resistors connected in series in Photograph 55(a)*). Then these resistors are in series. Like, if you look at the cells, cells of a torch they are connected in series because each cell is following the other cell so they are connected in series. Same thing with resistors if they are connected like this (Photograph 55(a)), they are connected in series:

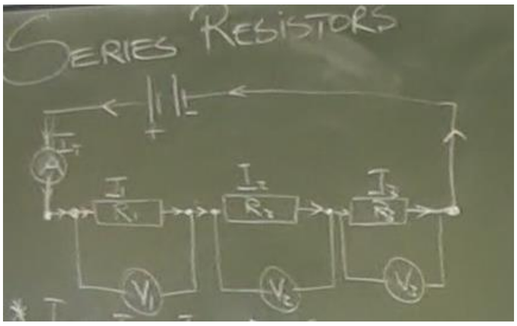


Photograph 55(a) Resistors connected in series

Photograph 55(b) Resistor connected in a series

Sipho: And then if this is resistor number 1, this is resistor number 2 and then this is resistor 3 (*teacher labelling the resistors in their orders, see Photograph 55(b)*)… And then now, if I want to connect a voltmeter across each resistor, so I will connect a voltmeter across each resistor which means each voltmeter must be connected in? [**Learners**: In series]. Parallel! Voltmeter is always connected in parallel (*writes on Photograph 55(a)*).

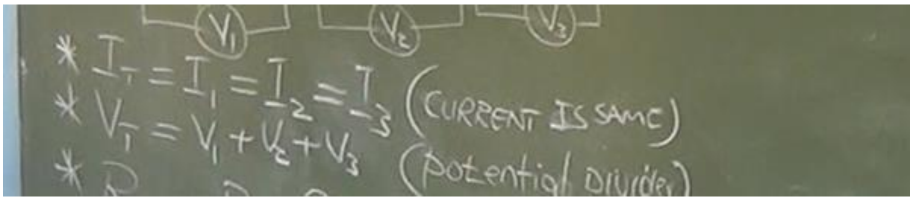
Photograph 56(a): Voltage across series resistors



Photograph 56(b): Series Circuit

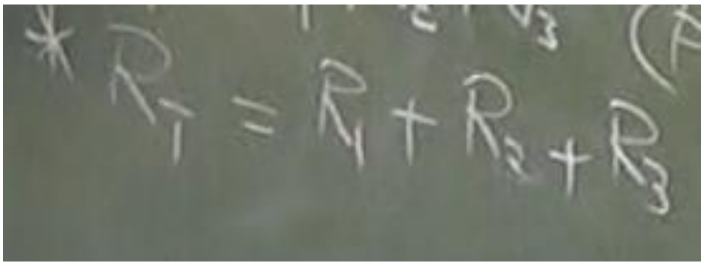
Sipho: And then now if I want to measure the potential difference across this (*pointing at* R_2) then I am going to connect another voltmeter here (*across* R_2) and this will be voltmeter number two (Photograph 56(b)). So, now the thing that you need to know about resistors that are in series. One, about the current it flows from, that‘s the principle of conventional current, it flows from positive to the negative and looking at current because current is the flow of charges, it‘s not easy to deal with the current because you cannot say this is the current this is where the current is (*teacher pointing at the circuit*) because we talk of charges…to see if resistors are series, the first thing that you do, you put the arrow (*teacher drawing an arrow* *from the positive terminal through R_1, R_2, R_3 and back to the positive terminal of the battery*)…remember we said current cannot go where the resistor is big, it goes where *i-resistor incane* (there is a small resistor). Which means if we trace the current across the ammeter, so which means the current *izoqonda lapha angisho* (will go straight here isn‘t) Then it‘s going to pass this resistor (R_1) and go through this resistor (R_2) it doesn‘t go to this voltmeter because it has high potential difference. [**Learners**: high resistance (loudly)].

Sipho: *Ayiyinjalo lapha okune high resistance khona, so ayiyi kuma voltmeter* (current does not go where there is high resistance so it does not go to the voltmeters)…current *umangabe kuyi* series (when it is in series), *ama-resistors wakho umangabe ekwi-serie,s current yakhona iyafana, uma ama-resistor wakho eku-series current iyafana azoba ne-current efanayo* (when your resistors are in series, their current is the same, if your resistors are in series, current is the same, they will have similar current)…it means that I_T=I_1= I_2=I_3 (*as the teacher talked, he wrote this on the chalkboard* – Photograph 57(a). So in series resistors we say current is constant throughout the circuit. Looking at the potential difference, potential difference is divided. This means that the total potential difference is equal to V_1+V_2+V_3 (see Photograph 57(a)). The current, if you combine this current it must give you the total current. What does that mean, which means a series circuit is a potential difference divider, it‘s a potential difference divider so it divides potential difference.



Photograph 57(a): Total current and total pd in series circuits

Sipho: So, for resistance, *lama resistor lana (pointing at the three resistors) uma uwahlanganisa kumele akunike* (when you combine these resistors they should give you a) total resistance so we simply add the resistors (*as he talks he is writing the following on the chalkboard* – Photograph 57(b)):



Photograph 57(b) Equation for total resistance in series resistors

In the previous episode the teacher focused on simple electric circuits with one resistor, in this episode, Sipho extended on more resistors connected in series to scaffold electric circuit knowledge, for concept continuation to support learners‘ knowledge building. This was noted in the teacher‘s explicit pedagogical practice using a mixture of detailed drawings on the chalkboard as representations (REP), with clear explanations of the interrelationships between different drawings, and the practical context-sensitive example of torch cells to make the lesson relevant. The teacher explicitly linked torchlight cells to resistors in Photograph 55(a). While Sipho did not explain what cells are in the torchlights, given that in everyday language they are generally referred as torchlight batteries than cells, I noticed that the torchlight example brought to light the idea of series connections in a circuit. Scott et al. (2011) posit that ―science learning inevitably occurs against a backdrop of everyday or spontaneous ways of talking and thinking about phenomena‖ (p. 6), which was also important for Sipho to make links to integrate, though he did not make the link to differentiate between the everyday and scientific ideas of series as it related to a torchlight and electric circuit. This addresses the importance of teacher‗s awareness of related views and the ability to move between social languages according to context, talking science in some contexts and talking an everyday social language in other contexts (Scott et al., 2011).

In a context with limited teaching and learning resources, the use of hands to demonstrate concepts extension and relations becomes important, as noted in Photograph 55(a) when Sipho emphasised the linear nature of the drawn resistors, demonstrating sequencing of the resistors in series, and in Photograph 55(b) Sipho demonstrated the idea of ‗across‗, voltmeter connected across a resistor. To promote learners‗ scientific conceptual knowledge and showing them how the scientific concepts fit together in an interlinking system, Sipho tried to explain the series circuit which was done unsystematically to promote coherence and easy understanding. This was observed when the teacher asked about the connection of a voltmeter in measuring potential difference across each resistor while pointing at the drawn series resistors instead of focussing on one resistor, and learners shouted ‗series‗ connection for the voltmeter connection in measuring potential difference across. This represented the concept of explaining what is difficult to understand and to teach (WDT) about current flow, particularly the abstractness of current flow and principle of conventional current not being consistent with charge flow. To address the difficulty of ‗across‗ connection, the teacher used his hands (Photograph 55(b)) to demonstrate what ‗across‗ means in the context of resistors and voltmeter connection.

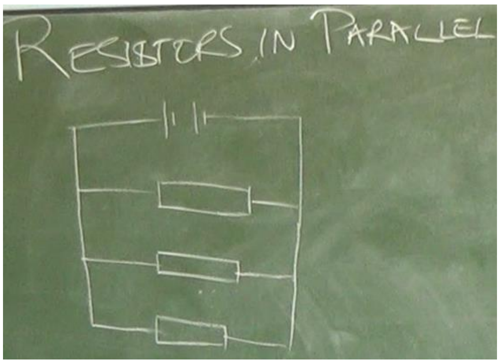
Moreover, to address the difficulty of current flow in a series circuit within a resource constraints context, Sipho used code mixing between IsiZulu and English languages and arrow strategy (Photograph 56(b)) to demonstrate the flow of current from positive terminal travelling one path for series circuits until it comes back through the negative terminal of the power source. Zhou et al. (2016) explicates that identifying challenging concepts requires teachers to have knowledge of gate-keeping concepts in a specific topic, and which concepts might be difficult to either teach or to learn, which was noted in this episode when Sipho explained the concepts of current flow in series resistors, potential difference across resistors, and total resistance for series resistors. The chalkboard was important for teaching and explanation of the content, as noted in Sipho‘s different drawings and written equations, which shaped the non-interactive/authoritative communicative approach. The teacher responded to his instructional questions while learners‘ participation was limited to completing teacher‘s sentences and confirming evaluative answers. Thus, this episode focussed on the equations to calculate total current, potential difference and total resistance in series circuit connections (Photographs 57a & 57b), and the explanation of current flow in relation to resistors in series connection and potential difference thereafter in the series connection.

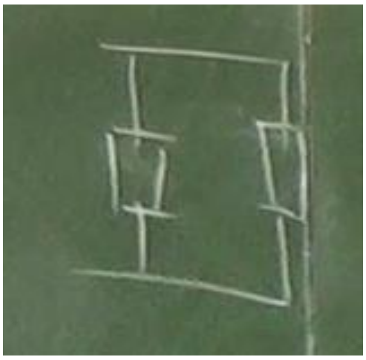
After the total resistance equation in Photograph 57(b), Sipho switched to teach parallel resistors and the following episode demonstrates his practice. Sipho argued during VSRI that he had to start with series circuit explanation because ―*this one (series) is simple and then parallel are challenging*‖ hence teaching parallel circuits after series circuits due to what the teacher considers difficult to comprehend (WDT) which then led to his content sequencing (CSA).

Lesson 2, Episode 2

This episode focussed on the diagrammatic representation of the resistors connected in a parallel circuit. Electric current movement in this particular circuit was explained and demonstrated through the drawn diagrams. In his teaching, the teacher makes constant micro links to content of the previous episode within the current lesson. Also, teacher talk dominated this section of the lesson. Below is the teacher talk for the episode:

> Let‘s look at parallel resistors, let‘s compare these with the parallel resistors so that we are going to understand this better. We need to compare this to the parallel resistor. Now resistors that are in parallel, so now if you have, take the same resistors (*as the teacher talks, he draws a circuit diagram – Photograph 58*)

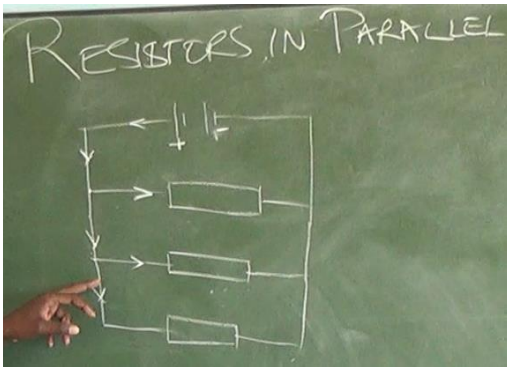




Photograph 58(a) Parallel circuit connection Photograph 58(b) Parallel resistors

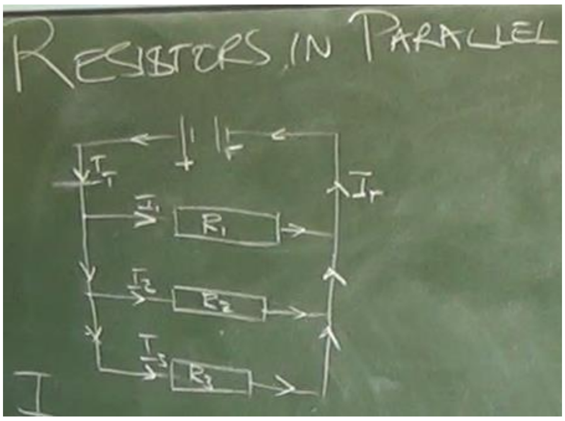
Now let‘s say we have these resistors now they are connected in parallel. It‘s not always that resistors will be arranged like this. It can also be like this (*drawing two resistors in Photograph 58(b)*), still these resistors are parallel. Then for you to make this easier for you because you are given the circuit in various ways so that you can see whether it is parallel or series, firstly look at the law of conventional current then now you start drawing your current with arrows (*indicating with arrows on the circuit – Photograph 59*). *Nansi iyahamba lana* (here it is moving) (*referring to current as he draws arrows*), *iyaqhubeka current mayifika la* (current continues when it gets here) (*pointing at the T-junction of the circuit*). Definitely some will take this direction (*indicating the direction to the first branch of the resistors from positive terminal*), *kuphinde kube khona eza ngakuphi* (and another one will take which direction?) [**Learners**: Straight].

Sipho: Once it splits, it means it is parallel, *yabona la akukho la ejika khona ihamba straight ku-series* (you see here, there is no point where it turns, it moves straight in series (*referring and pointing at Photograph 56(b)*). But here (*referring to Photograph 59(a)*), there is some current going this way and there is some current continuing. The current here (current that went straight from the T-junction) *ayisafani nelapha* (is not the same as the one here) (*referring to current that went to the first branch, to R_1*). *Kukhona encane eshonelena* (there is a bit that went this direction) (referring to the first branch), and another one went this direction (*referring to the current that went straight from the T-Junction*).



Photograph 59(a) Arrows showing current flow in a parallel circuit connection

These current come together and do what? [**Learners**: they meet]. They meet as current I_1, I_2, and I_3 to give total current on the other end towards the negative terminal (*in Photograph 59(b)*). To see that resistors are parallel is easy if you are going to trace the current, if it splits then its parallel, definitely these ones are parallel (*pointing at Photograph 59(b)*). Now since we talked of current, let‘s say you look at the current here we said it is the same (*referring* *and pointing to Photograph 56(b)*) but here (*pointing at Photograph 59(b)*) current is not the same. We have R_1, we have R_2, we have R_3 (*labelling the circuit in Photograph 59(b)*) and then definitely this is the total current (*labels total current just before it reaches the first T-junction*) and then this will be I_1 (*just next to R_1*), this will be I_2 (*next to R_2*) and this will be I_3 (*next to R_3*). So the total current that comes out from the positive terminal splits then when it goes back towards negative terminal after the resistors it becomes total current (*explaining using the circuit in Photograph 59(b)*).



Photograph 59(b): Showing total current splitting at T-Junction

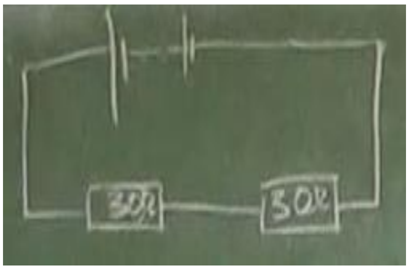
Following from the previous episode 1 of the current lesson, Sipho suddenly switched from series resistors explanation to parallel resistors. Interestingly, however, Sipho compare resistors in series and those in parallel circuit connection with respect to the alignment parallel resistors in the circuit diagrams (Photograph 58(a) & (b)), and flow of current (Photograph 59(b)). Though the teacher has communicated that he was to compare the series and parallel resistors, in series circuit explanation, he gave equations to use for current, resistance, and potential difference, but did not provide these for parallel resistor connection in this episode but provided later in the lesson. Moreover, it was interesting to observe Sipho making micro scale links to develop the scientific story and promote conceptual understanding while encouraging concept development and continuity. This was seen when Sipho compared the current flow from series resistor connection in Photograph 56(b) and that of parallel resistor connection in Photograph 59(a). Furthermore, similar to the previous teaching episodes, Sipho continued to code-mix between IsiZulu and English languages to explain science concepts, especially when explaining the multiple routes of current flow in a parallel circuit connection. The teacher successfully did this as he used his hands to demonstrate on the chalkboard (see Photograph 59(a)) the explained process through code-mixing though impact of code-mixing on the scientific conceptual understanding was not confirmed with the learners. Additionally, it was interesting to observe Sipho track through the current flow with arrows from the positive terminal, to when it gets to T-Junction and explain how it gets split in the point, to when the current comes back as total current towards the negative terminal of the battery. In this instance, the teacher used his available resource (chalkboard) effectively to show the process of current flow in a parallel circuit connection.

Similar to his previous episodes, Sipho dominated this episode and only involved learners to either complete teacher‗s sentences or to respond to teacher‗s confirmatory questions. In line with this approach, the teacher kept on talking even while writing on the chalkboard. This practice was concerning especially when explaining the current flow using arrows in Photograph 59(b), the teacher drew and explained while facing the chalkboard and some learners were talking behind the teacher. Also, though circuit was not completed in Photograph 58(b) but it was remarkable for the teacher not only to show the resistors alignment in Photograph 58(a) but also mentioned that resistors could be aligned as demonstrated in Photograph 58(b). Additionally, I observe that when Sipho explained series and parallel circuit connections, he did not constantly referred to the worksheet or examination guidelines as he did in lesson 1. Sipho‗s pedagogical reasoning during VSRI suggested that his electric circuit teaching was shaped by his teaching experience and learning experience of the Electricity topic during his electrical engineering studies. Lastly, the teacher concluded the lesson by giving an activity for learners to do at home and this was attended to in the subsequent lesson 3. The following section presents the third observed lesson.

7.2.3 Lesson 3: Solving calculations for series and parallel resistor connections

Lesson 3, Episode 1

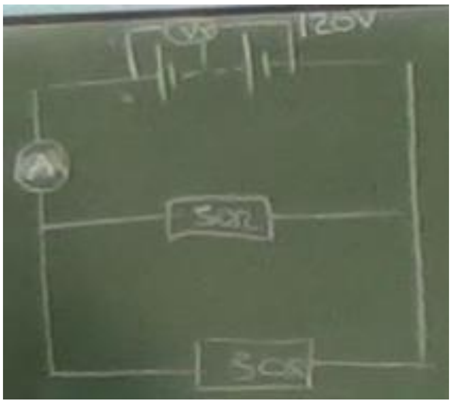
Following from the previous lesson‗s content teaching and homework given to learners, in this first episode of the third lesson, Sipho focused on homework corrections, solving resistance calculations for both series and parallel circuit connections. Sipho continued to use a non-interactive/authoritative approach as he read, analysed and solved the potential difference calculations while learners sat quietly looking at the teacher. As the teacher engaged with the corrections, he introduced a new strategy of minimizing a circuit with two or more resistors (Photograph 60(a)) to one resistor (Photograph 60(b)) for calculation purposes. The intention was to teach learners how to simplify a circuit, given the challenges of solving complex circuits. Sipho argued during VSRI that he minimised the circuit to address learner difficulties (what is difficult to learn) in solving complex circuits. In solving the circuit calculations, it was interesting to observe the teacher drawing from the equation in Photograph 57(b) of the first episode in lesson 2 to calculate the total resistance of the minimised circuit. Although he took it for granted that learners would know how to substitute in calculating total resistance, as he did not write the equation and substitute on the chalkboard. The teacher continued to draw from his prior knowledge of working with Ohm's Law (as covered in lesson 1, episode 3) to calculate potential difference when given the total resistance of the minimised circuit and electric current.



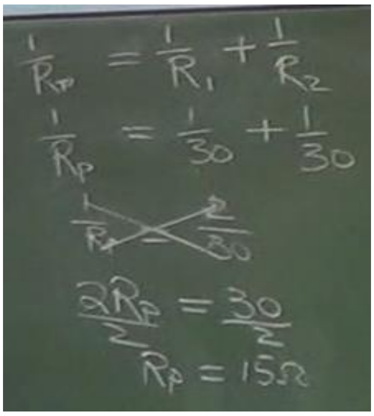
Photograph 60(a) Series Circuit Diagram

Photograph 60(b) Minimized Electric Circuits

After getting the total resistance for the series resistors in Photograph 60(a) and the calculations of potential difference using the minimised circuit in Photograph 60(b), Sipho focussed on solving calculation for resistors connected in parallel. Below is the teacher talk during the lesson,



Photograph 61(a) parallel circuit connection



Photograph 61(b) Total resistance for parallel circuit

Photograph 61(c) Minimised circuit from Photograph 61(a)

> **Sipho:** Then come to this one (*pointing at the parallel circuit connection in Photograph 61(a) and its calculations in Photograph 61(b)*), *uma ama-resistor e-parallel uyabona ukuthi asinikeza ubani, 15* (when resistors are in parallel can you see that they give us what, 15). The same resistor 30, 30 they are now connected in parallel, total resistance decreases so which means when resistors are parallel the total resistance is smaller than the smallest resistor in the circuit.
>
> Already we did calculate R_p=15 Ohm's (Photograph 61(b)) and then two now, calculate the total current. The simple circuit is going to have one resistor that is smaller, it is 15 Ohms (Photograph 61(c)) … We know that the voltmeter measures 120V... Now potential difference which is here its 120 volts and then we do not know the current…Which formula are we going to use to calculate the current here… The resistance is 15, potential difference 120, the current, we want it…Which means it's going to be 120 divided by 15. I is equal to 120 divided by 15, what are you getting? [**Learners**: 8]. It's going to be 8 Amperes.

The teacher used problem solving to teach parallel resistors and drew a circuit with two parallel resistors (Photograph 61(a)). It was interesting to observe the teacher drawing the series circuit with two resistors first (Photograph 60(a)), minimised it to one big resistor through verbal calculations and then drew the minimised circuit (Photograph 60(b)). Sipho links the demonstration with parallel connection as he uses the same resistors as in the series circuit but connects a parallel circuit in Photograph 61(a). Symbolic representations and diagrammatic representations were used in drawing the electric circuit and calculating the total resistance for parallel circuits and electric current through Ohm's Law equation. The teacher used an integrative approach for different levels of representations (REP) to promote knowledge building. Sipho highlighted the principle of cross-multiplication through the calculations (Photograph 61(b)), and then drew a minimised circuit (Photograph 61(c)) as he talked about the simple circuit reduced from parallel circuit. Interestingly, yet concerning, was the teacher's approach to electric current calculation towards the end of this episode, where Sipho only mentioned the calculation verbally while taking for granted that learners know what and how to substitute and manipulate the equation until the final answer of 8 Amperes as indicated in this episode. The implications of this practice are that learners may not have a feel for scientific expressions, and in turn lack guided mathematical manipulations which negatively affect learners' conceptual understanding of content and science processes in symbolic manipulations (Sherin, 2001). Also, the observed practice does not seek to integrate learners in the mathematical manipulations in physics, which is concerning especially when considering that learners have negative attitudes to the mathematical calculations within physics (Emanovský & Gonda, 2020).

Sipho dominated classroom talk, analysed diagrams, and did all calculations without drawing from the learners' prior knowledge (LPK), irrespective of whether it was classwork or homework, and learners were only involved in procedural aspects to confirm cross-multiplication and to calculate the final answer for electric current. This episode represented a non-interactive and authoritative communicative approach, even though towards the end of the episode there were elements of interactive/authoritative approach when Sipho used a sequence of closed confirmatory questions to encourage limited learners' participation. Furthermore, Sipho drew from micro and meso time scales on the knowledge of resistors in parallel and Ohm's Law, limitedly using learners' prior knowledge of resistors in series which had been done in the previous lessons. This episode was characterised by the teacher move between teacher talk, chalkboard (diagrams and calculations), notes from the examination guide, and worksheet, dominantly through non-interactive authoritative-communicating approach and IRE pattern. While there was evidence of conceptual teaching strategies (CTS) in this episode through teacher's modelling, coaching, making micro and meso scale links, emphasizing certain content knowledge and skills, moving between the symbolic and diagrammatic representations, it unfortunately promoted learners' passivity and is unclear whether learners' science knowledge was developed when they only completed teacher's sentences and confirmed evaluative answers.

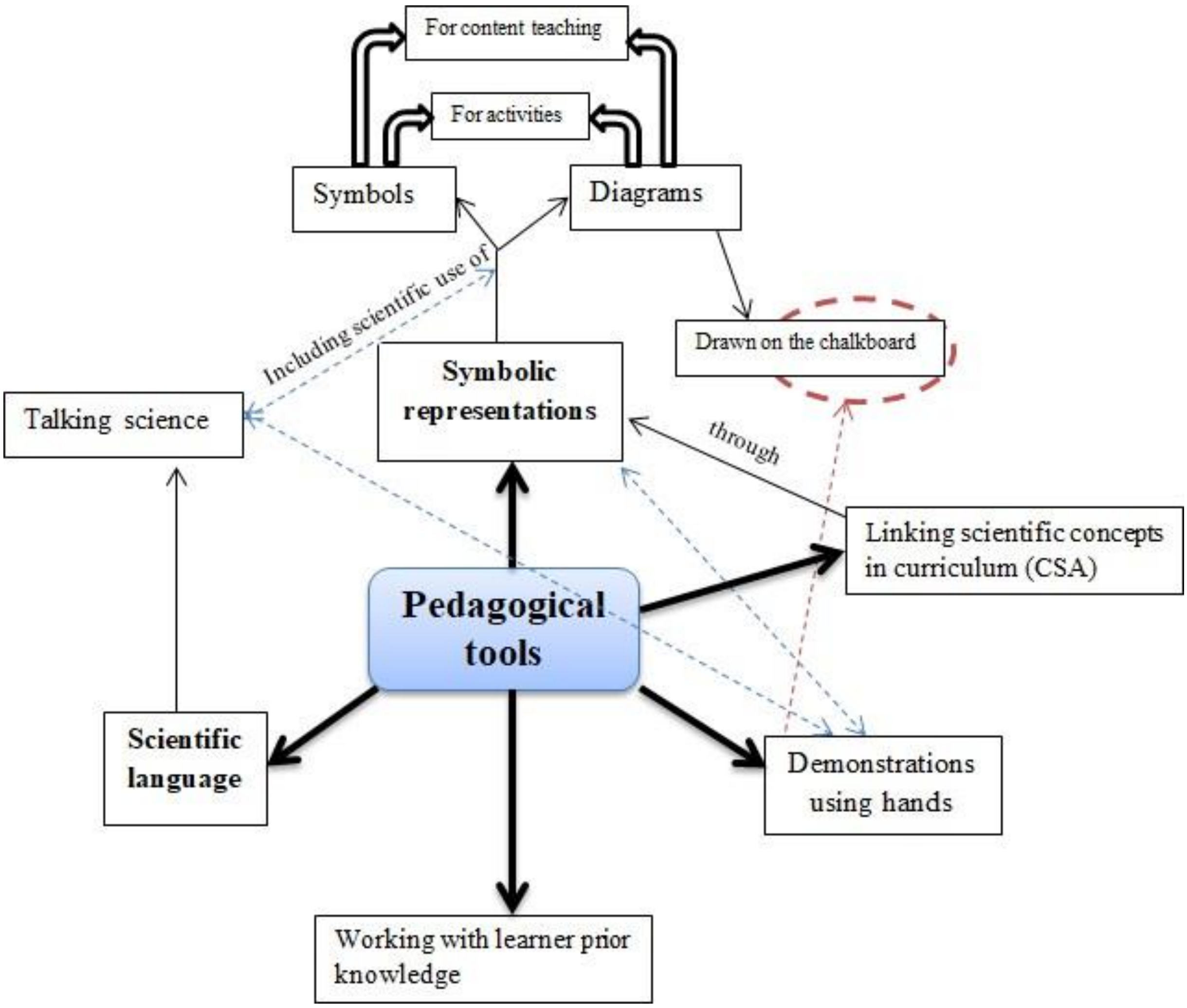
To continue with his approach, after the calculation of total resistance in parallel circuits, Sipho gave learners classroom activities and gave learners approximately 10 minutes to do the activities, but did the calculation activities despite having given these to learners to work out. This was Sipho's approach to all activities, and here the activities focussed on the calculation of potential difference across each parallel resistors, current in each parallel resistors, total resistance for parallel resistors, and total resistance for combined parallel and series resistors after minimising parallel resistors to one big series resistor. Of importance, Sipho coached learners on how to approach a complex electric circuit, which did not appear to be successfully done as learners, though coached, but were spectators in the process. Furthermore, the teacher pointed at the drawn parallel circuit on the chalkboard more often. The drawn diagrams on the chalkboard acted as a reference point to what was explained by the teacher. Even though it is familiar for teachers to use their hands during explanation, in this context the use of hands was to emphasise content knowledge skills and to demonstrate electric current and potential difference across resistors and in the entire circuit as drawn on the chalkboard especially on how a parallel circuit is a current divider. Lastly, Sipho closed his lesson by directing learners into the worksheet for a class activity which was carried over as homework activity.

7.3 Chapter summary

In this chapter, I presented, explained, and analysed Sipho‘s enacted pedagogical content knowledge of Electricity topic and his pedagogical reasoning that influenced his observed pedagogical practices of Electricity topic. Classroom observation and video stimulated recall interview data sets informed the analysis in this chapter. Emerging from the analysis, Sipho‘s teaching was largely activity-centred. The teacher made use of pedagogical tools such as symbolic including diagrammatic representations which were all written and drawn on the chalkboard; teacher made use of hands to demonstrate resistor alignments in a circuit, current flow, and other scientific processes; references were also made to sub-microscopic behaviour of concepts taught; and the scientific language of talking about Electricity concepts and processes. These tools were not linearly used but there was back-and-forth in their usage. Of these tools, symbolic representations in the form of symbols and diagrams were dominant in the observed lessons while Electricity concepts and processes were barely represented at macroscopic and sub-microscopic levels of representation. Interestingly, scientific language was encouraged within and across lessons in enculturating learners into scientific discourse. Figure 10 below represents the complex nature of pedagogical tools used by Sipho and the interrelationship between these tools as used in Sipho‘s classroom.

Figure 10

Teacher Sipho's pedagogical tools used during the Electricity lessons



While making links between the various pedagogical tools used, the teacher also made content and pedagogical knowledge links across lessons and from within lessons in his attempt to develop a coherent scientific story for Electricity topic and to help learners comprehend what the teacher perceived as difficult for learners to understand (WDT/L). These links were justified in VSRI as important for formation and continuity of concepts within Electricity topic and across curricular (CSA), where the teacher would constantly remind learners and draw from their prior knowledge (LPK). This was the reasoned important conceptual teaching strategies (CTS) and the possible factors that influence it from the teacher‘s perspective. The following chapter presents and analyses data from the classroom practices of Thando to uncover how she taught the topic of Electricity to her Grade 10 physical science classroom.

CHAPTER 8

Thando's tsPCK to support Electricity knowledge building: Data Analysis

8.1. Introduction

The current chapter present Thando‘s observed classroom lessons for the Electricity topic and the consideration of Thando‘s pedagogical reasoning for the observed teaching practices. This pedagogical analysis presents what the teacher said and did; the development and facilitation of concept formations and understanding, the pacing and sequencing of the content during each lesson. The following analysis begins with the overall overview of all observed and analysed lessons. Then each lesson is described in detail from the first till the fourth observed lesson.

8.2. Thando's classroom practices: Lesson observation narratives

There were 85 learners in Thando‘s Grade 10 physical science classroom, and four Electricity lessons were observed. All the lessons were taught in a science laboratory, which is used as a science classroom. The first lesson ran for 33 minutes, 12 seconds and it came immediately after lessons on electrostatics. In this first lesson, Thando introduced the idea of electric current and symbols of the electric circuit components. Thando explained electric current and acknowledged components that could be difficult for learners to learn when she made a link to differentiate between conventional current and electron flow; and between a battery and a cell. All these were negotiated through the use of symbolic representations in Photograph 62, which showed a sub-microscopic nature of current and charge flow and represented WDT because of Thando‘s awareness of difficult sections of the topic. Moreover, each component of an electric circuit was described and drawn on the whiteboard and continuously referred to during the lesson. These components were brought together in a drawn simple electric circuit (Photograph 63). Learners‘ prior knowledge was prompted throughout the lesson, and Thando used analogies in learners‘ home language (IsiZulu language), and linked to scientific knowledge through English language (LOLT). The interactive / authoritative communicative approach was dominant in this lesson, which played out mostly through the traditional triadic IRF (feedback) patterns and occasionally IRE (evaluation) of interaction.

The second lesson lasted for 48 minutes, 48 seconds, and Thando brought together the individual electric circuit components that were discussed in the previous lesson. She showed learners how each component looked like, described with reference to how they are individually connected in a circuit and the role of each component in an electric circuit. These components were shown as separate entities of an electric circuit to demonstrate their actual connectivity in making up a complete electric circuit at a macroscopic level of representation. Moreover, this lesson concentrated on emf, with a special attention to potential difference which causes current flow. Ohm‘s Law and its symbolic representation were important for Thando‘s explanation, and the lesson ended with problem solving calculations. The teacher dominated the lesson using the authoritative communication, because there was non-interaction to explore different learners‘ ideas but to develop the scientific story (meso).

The third lesson lasted for 35 minutes, 37 seconds and focussed on drawn series and parallel electric circuit connections, and the calculations for total resistance in series and parallel circuit were foregrounded in Thando‘s explanation. The whiteboard was instrumental in Thando‘s explanation of symbolic representations of scientific processes. The lesson lasted for 35 minutes, 37 seconds. Lastly, the fourth lesson was centred on the idea of mathematical calculations for current in both series and parallel circuits. The teacher dominated classroom talk and mostly used the symbolic and diagrammatic representations (REP) on the white board. Subsequently, evaluative and interactive communicative approach was dominant in the last two lessons. The following sections demonstrate a detailed analysis for each lesson. I begin with lesson 1, episode 1 below.

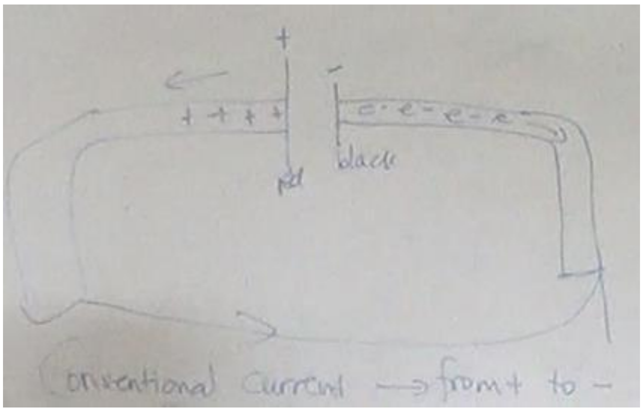
8.2.1. Lesson 1: Introduction to electric circuit components

Lesson 1, Episode 1

Thando used a white board to draw diagrams to present scientific content meanings. She introduced the lesson by defining electric current, demonstrated the flow of electric current and electrons in a diagrammatic representation of a simple circuit (Photograph 62), and highlighted the idea of conventional current. The lesson further introduced and developed the scientific story, micro scale level, about electric current, which was dominated by teacher talk using authoritative and interactive communicative approach.

> **Thando**: What is current? Current, it is the rate at which charge flows. Whenever we talk about the direction of the current your arrow must move from where it‘s positive and move

towards the what? If it‘s said that it is a full circuit it means that your current moves in an anti-clockwise direction (pointing to diagram on Photograph 62 drawn on white board) and so the fact that it was agreed on by the whole world, gives it the named conventional current. What do we mean by conventional current? We mean that the current always flows from positive to negative, so the direction of the current is always from positive to negative. Senzelani ke (*the reason we do this*), it‘s because electricity is very dangerous… now the big question is, then what flows from the negative to the positive because there is something flowing from here to there you see (points to Photograph 62 on the white board) because this one is negative, right? So it means on the negative side what is excess, what is excess on negative? [**Learners chorusing:** Electrons are excess]. The electrons are excess. So you won‘t have electrons that will flow in the anti-clockwise direction, to the clockwise direction is the electron flow and to the anti-clockwise direction is the current flow, you see? So the charges or the moving charges that is the current but to this direction (*clockwise*) those are the electrons. Action then, when we mention that in the wires there is action because of the flow of these two things, flow of current and the flow of electrons. If you don‘t believe me saying that there is a flow of current, there is current, there is something happening, you can just cut your Iron cable at home because I can assure you that you are very good conductors of electricity okay? So you can just plug one side and hold both ends of the cut cable so you can see that you are a good conductor…No do not do that, it was a joke. You must know that you are a very good conductor of electricity that is why you get shocked….



Photograph 62: Conventional Current (and electron flow) representation

It was important for Thando to explicitly explain the concepts individually and connectedly, showing learners the relationships of the concepts. While there were repeated explanations, it was essential for Thando to make a distinction between the meanings of clockwise and the anti-clockwise directions in relation to conventional current flow and electron flow, to link the concepts of current and electron to make the content accessible to learners. This way of teaching represents curricular saliency (CSA) which embraces teacher‘s knowledge of core and peripheral concepts that enhances the transformation of specific content (Rollnick & Mavhunga, 2014). The teaching approach included a combination of teacher talk and symbolic representation, and learners were included to complete the teacher‘s responses. The teacher used the evaluative authoritative because the intention was to get the answer that learners already knows, as they gave a brief answer to a specific question. I noticed during the explanation that Thando mentioned the moving charges that were described as current (negative to positive terminal), and did not explain how it differed from the already described conventional current (positive to negative terminal) for pedagogical link-making to support knowledge building by making links between scientific concepts (charges and current, and conventional current).

To emphasise the idea of current flow, Thando links the science content (electric current flow) with real world phenomena (electroshocking) when referring to learners as being good conductors of Electricity. However, the teacher did not give reasons for human beings to be good conductors of Electricity. The intention was to promote conceptual comprehension and arouse learners' interest by introducing a complex scientific phenomenon from simple real world scenarios that learners are familiar with or that can stimulate learners' interest (Scott et al., 2011). It is expected that the teacher introduce the situation through discussion, but learners must be able to link it to their life experiences. That linkage of life experience and the scientific concept bring about understanding (Scott et al., 2011). The challenge was that learners were not afforded an opportunity to present their views and understanding of the world situation introduced by the teacher. Thus, there was a lack of learner's expressions about their understanding of the world phenomena to note whether there was conceptual learning that took place.

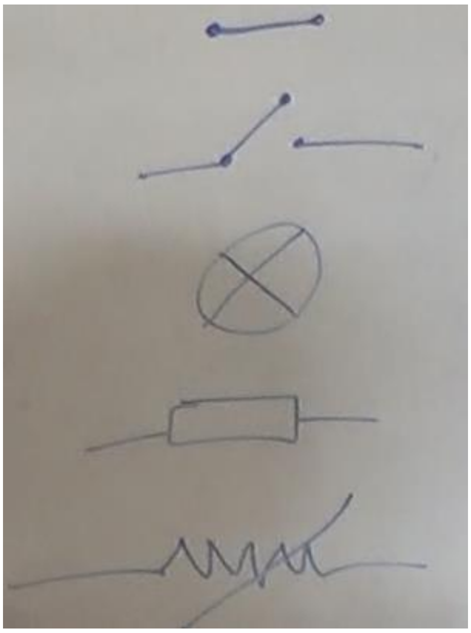
Though not explicitly stating it, Thando makes a meso-scale continuity link when drawing from learner prior knowledge of conductors of Electricity which was done in the previous lessons under electrostatics. This episode is dominated by the teacher presenting a specific scientific point of view, which makes the episode non-interactive and authoritative in terms of communicate approaches. It is because the teacher made the links, rather than learners, between the life experience and the scientific concept that shaped this communicative approach, as Lehesvuori and Ametller (2021) posits that the nature of the links can influence the teachers' choice of communicative approaches. Thando used a white board to draw diagrams which is pictorial representation at symbolic level (Johnstone, 1991; Gabel, 1999), to help her negotiate scientific meanings of the taught content. Gabel (1999) asserted that it is difficult to teach at the symbolic level, because it makes science complex. Notwithstanding this, (Machado & Mortimer, 2007) said science is essentially symbolic and students need to learn the social language of science with all its specificity, such as formula, graphic representations, electric circuit symbols, and mathematical equations.

Lesson 1, Episode 2

Thando continued to build the scientific story by outlining the components of an electric circuit necessary for the electric current to flow and/or to be measured. She explained and linked the function of each component to electric current, particularly in the electric circuit connection, using symbolic representations (Photograph 63) during explanations and demonstrations. In the following episode, Thando used closed confirmatory question/answer (CCQA) which is further represented by IREvaluative/Feedback and interactive/authoritative communicative approach. She used the authoritative during the explanation of scientific concepts and interactive during the close confirmatory practice. Below is the continuation of teacher talk from episode 1,

> **Thando**: Now before you start creating something that you call electricity you must know the components of electricity. There must be a power source, what do we mean by power source? We mean this is where we get voltage, it‘s a voltage provider … So cell, battery, generator anything where we can get power we call it a power source, and then for electricity to move, it‘s not electromagnetic waves that we talked about in Grade 9… electricity can only flow through a connecting wire and when it is red, then it is positive and when it is black, then it is negative... The difference between a cell and a battery, a battery is when you have many cells together. But when it's just one cell, is a cell … when it‘s four, four cells, but a collection of two or more cells we call it a battery, a battery which is the power source … so whatever that use the electricity or make use of the electricity, we call it a resistor because it resists the flow of current, the current was just flowing, but now it's being held back.
>
> **Thando**: …So what happens is, the electric current is just flowing as electric current, but once it changes, if it is in the heater, it will change the electric energy to heat energy, you see? [**Learners** chorusing: yes]. We spoke about the preservation of energy from grade six we mentioned that energy cannot be created, energy is never destroyed, it can only change from one form of energy to another, but once it lights the bulb it becomes the what? [**Learner respond***:* light energy] When it makes the radio to go on then it changes the energy into what? [**Learners chorusing**: sound energy] …Now there are components that we spoke of when we spoke about circuits, I hope you still remember… This one? (*teacher points at the drawn circuit symbols in Photograph 63*), [**Learners chorusing*:*** closed switch]; and this one? [**Learners chorusing:** open switch]; and this, [**Learners chorusing**: light bulb]; this one, [**Learners chorusing**: resistor]; and this? [**Learners chorusing**: resistor] this? *(asking again)*, we call this a variable resistor or rheostat, it means that this type of resistor doesn‘t come with a certain value it comes with no value … you can change the resistor to where you want. Okay now you remember when we drew the circuit diagrams in your grades 8, 7 and 6 that you had the components of the circuit and where your grandmother would come and say when your circuit is completed that you must not touch it because? [**Learners uniformly**

respond: kunomlilo (‗*it has fire'*)] Okay but what does the old woman mean by saying there is fire? Obviously you know there is no fire flowing inside the conductors, you know when there is fire, and fire burns right? [**Learners chorusing**: yes] For her to say there is fire is because she does not understand that the charges are flowing but now you know so you can tell her it‗s not fire but charges flowing you see? [**Learners chorusing**: yes].



Photograph 63: Some Circuit Components

Thando: To draw the circuit one must have a what? The number of cells that you will be drawing, and then you must have what? [**Learner respond**: wires] And then you must have the components we have been inserting, one component that we use to measure the current, are we clear [**Learners chorusing**: yes] And we call that what? Ammeter. An ammeter is used to measure the current, and in the circuit it is connected in series, which means you connect it along with other components, you see? [**Learners chorusing**: yes] But then there is another, what do we call it? [**Learners**: Voltmeter] Another one called a Voltmeter and it is connected in parallel, which means I can‗t put it here, if I want to put it in, I will just put it above the cells and if I want to measure the resistance I will place it below the resistors.

In the first part of the teacher talk, the teacher‗s intention was to clarify meaning of different concepts through the use of macro-time scale to help learners follow the development, connection, coherence, and continuation of topic and concepts to develop and build a scientific story. This intention shaped the non-interactive/authoritative communicative approach which could be a mismatch with the pedagogical link-making to promote continuity using meso-time scale, because Thando disregarded drawing from the learners‗ prior knowledge (LPK) of previous year. As the lesson continues Thando included learners by answering the closed confirmatory questions, and these questions were further used to correct misconceptions and expanded learners‗ knowledge through effective explanations. There was a combination of curricular saliency where the teacher reflected on the pre-concepts using the macro-time scale to explain the concept of current, with the combination of IRE and IRF to promote concepts continuity and develop scientific story (Scott et al., 2011). According to Akinyemi and Mavhunga (2021) curricular saliency encompasses the understanding of several topics in relation to the entire curriculum, core and subordinate concepts. While it is acceptable for Thando to use the interactive/authoritative communicative approach in this part of the lesson, which is necessary to transmit the scientific concepts that are distinct in nature, from the learners' chorus response they seem to know the meaning of an Ammeter and Voltmeter. To support the learner's development of meaningful comprehension of abstract scientific concepts, the teacher disregarded learners' prior knowledge because she perceived learners as ―usually not remembering past information‖ from the video-stimulated recall interviews, a reason she used IRE pattern.

Thando used the authoritative opening when she outlined the components of Electricity extending learners' knowledge about variable resistor, to present specific scientific view. The interactive part was used with meso time scale linking ideas from the learners' previous grades knowledge of Electricity topic to promote continuity. Thando further presented the concepts of cell, battery, resistor, variable resistor or rheostat, preservation of energy, and ammeter, and immediately explained them and their roles in an electric circuit to support learners' knowledge building and meaning in science context of Electricity topic. The teachers used a combination of curricular saliency (CSA) and conceptual teaching strategy (CTS) to constantly make links between scientific processes (energy conversion) and the real world phenomena (radio, heaters, and light bulb) of Electricity using grandmother's general everyday knowledge. While making this link, Thando differentiated between the everyday ways of explaining the components of the circuit from the grandmother's every day understanding of _fire' and the scientific way that it is charges that are flowing. Although the teacher was trying to raise learners' interest or helped them understand and comprehend the concept, she could have asked learners to determine how familiar they were about the concept. From the VSRI and semi-structured interview, Thando alluded to learners' lack of responses when asked questions, hence her authoritative communicative approach in this section of the lesson.

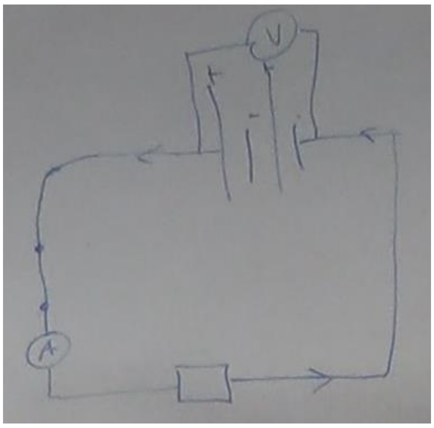
The practice in this episode represents Thando's multifaceted pedagogical approaches because her explanations shows that she did not take anything for granted during explanation of taught concepts individually and relationally for learners to see the connectedness and their continuation in curricular. Again, this represent Thando‘s CSA and CTS, and the importance of using symbolic representation to support scientific knowledge building, even though drawing from learners‘ prior knowledge was limited. It was the assumption Thando had about learner‘s nature of prior knowledge, even when they correctly completed her confirmatory evaluative statements. To continue with her scientific story, Thando connected different electric circuit components diagrammatically on the whiteboard in the following episode.

Lesson 1, Episode 3

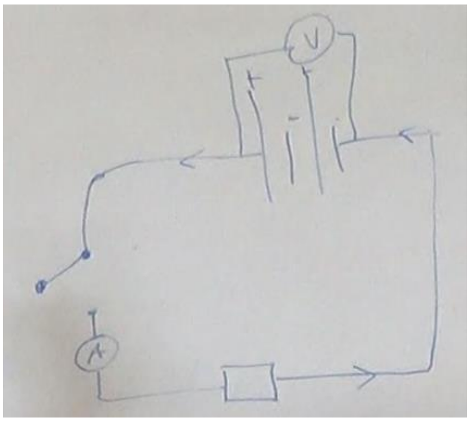
In this episode, Thando taught and explained one of the difficult concepts of _on‘ and _off‘ for electrical switch in circuits, because it required making links to integrate and differentiate everyday and scientific ways of explaining. Thando connected the individually described components of electric circuit that were presented in episode 2 to form a simple electric circuit in Photograph 64, and was used to explain the _on‘ and _off‘ of a switch and its implications to current flow in the circuit. The following excerpt demonstrates teacher talk and actions,

> **Thando**: Once a circuit is complete it must have 1. a battery, or a power source or cells; 2. it must have the connecting [**Learners chorusing**: Wires] 3. It must have a resistor or whatever it is that they are going to use, and it must have a switch whether they are going to use it or not. Everything has a switch, your kettle at home has a switch, everything has an _on‘ and _off‘, so a switch is there. Now listen to me carefully, I want you to understand something, you can see that when the switch is open, it means that the flow of current goes here (*using the arrows in Photograph 65 to show flow of current*) and when it comes here I told you that charge flow cannot just be jumping, it cannot be moving where there is no medium where it can move through. So it means that when it gets here nothing will happen, are we clear? [**Learners**: yes] So right now is the switch open or closed? (*referring to Photograph 65*) [**Learners**: it is open]. The chief switch is open because it is not allowing the current flow. So Sizwe[35] can you please close the switch for us? He has closed the switch that is why we‘ve got Electricity (*referring to a learner having switched on the classroom light*). Can you please open the switch for us? Now the switch is open (*lights off in the classroom*), can you hear what does it mean? [**Learners**: yes]. Whenever you close the switch you get light so whenever you open the switch, the light goes off. So at home when you want to sleep please open that switch. When you wake up in the morning you can say, _can you please close that switch‘.

[35] This is a pseudonym given to the learner that was called by the teacher during the lesson.



Photograph 64: Closed Simple Circuit



Photograph 65: Open Simple Circuit

The classroom context was used as the teaching tool, to show learners how the ideas of ‗on' and ‗off' of a switch works. The classroom lights were switched off (no glow in light bulbs) when Thando asked a learner to close the classroom switch, and there was glow in the classroom light bulbs when the learner closed the classroom switch, and the teacher confirmed that the observed glow (electricity) is because the classroom switch is closed so there is evidence of current flow. The important information was repeated and Thando used learners' everyday knowledge of a switch to represent the real world phenomena (switching on and off lights at home and in the classroom), and taught learners how to communicate scientifically when they want to turn the lights on or off at home. The teacher used interactive/authoritative communicative approach to demonstrate the ‗on' and ‗off' through the classroom switch as she led the learners through a sequence of instructional questions and answers. Another observed aspect was the use of language to draw learners' attention to the important information, ―Now listen to me carefully I want you to understand something‖, to explain a complex concept and process. This language signals teacher's acknowledgement of a difficult idea to comprehend (WDT/L) hence explicitly drawing learners' attention to it and using real world phenomena to exemplify the difficult idea. The drawn Photographs 64 and 65 played important roles in the explanations and demonstrations to show the continuous and discontinuous flow of current when the switch is either open (Photograph 65) and or closed (Photograph 64). The idea of medium for current flow was explained in the previous episode, so in this episode, the teacher makes a link to this idea to promote continuity which addressed the idea of switch being open and being closed in relation to current flow. From this idea of a switch in an electric circuit, Thando focuses on potential difference and emf in the following episode.

Lesson 1, Episode 4

From the above analysis, Thando focused on proceduralisation and described the series and parallel connections, and concentrated to the voltmeter connection across the power source or across a resistor. She explained that voltmeter measured voltage in Volts. Thando used code mixing from the learners' home language (IsiZulu) mixed with English, to present an analogy that demonstrate the idea of electromotive force (emf), while making a link to differentiate between emf and potential difference that are both measured in Volts. The following excerpt represents teacher talk,

> **Thando**: Now I want to tell you about the emf of the cell and the potential difference of the cell. See, if I have a pipe of water, listen to me carefully, if I have a pipe of water taking the water from here *ngiwasa lapha phezulu entabeni* (to the top of the mountain) and I have measured the water to be 25 litres from the tank. *Ahambe-ke lamanzi ukusuka lapha aze afike lapha entabeni. Uma sengiwahlangabezeza lapha entabeni lapha ade ehamba khona nge payipi, ngeke ngisawafica lawomanzi esengu 25 litres, ngizowathola engu 24 litres mhlampe noma engu 24.5 litres* (the water will move from here to the mountain. If I fetch the water from the mountain where they were travelling by pipe, I will not find the water to be 25 litres anymore, I will find it to be 24 litres maybe or 24.5 litres). What happened to the other 1 litre? *Angithi uyabona ipayipi linjani, limanzi so amanye amanzi amanzise ipayipi. Amanzi mancane wona asebenze epayipini ukuthi ngingawanake kodwa khona* (so you see how the pipe is, the pipe is wet so some of the water wetted the pipe. Little water was used in the pipe but there is water used). The same thing applies when the current is flowing, as it flows through the wires, voltmeters, ammeters, batteries, resistors as it flows, *ngathi imbongolo ithwele umthwalo* (it is like a donkey carrying a load), that's a load actually, you remember when we spoke about a load in technology? [**Learners**: yes] So it is carrying a load, when a donkey is hungry, what will it eat? It tries to turn its head around and eats from its load.
>
> **Thando:** Now what do I mean by that, I mean when the current is flowing on the conducting wires and through all these components of the circuit, when it flows there, a little bit of the current or a little bit voltage that was provided will be stolen by these little things. Let me do an example (*points to Photograph 64*) if each of these was what, was 4Volts, we mentioned that it's 2 and 2 right, [**Learners**: yes] So the Voltmeter gives you 4V which means they added the voltage from here which was 2V and the one here was 2V. Now the switch here is open which means there is no current flowing. Immediately you close the switch, this voltage just drops to 3.8V, what I said happens, some water will be left in the pipes, the ones lost we call them lost volts, this means when I had 4V minus 3.8v which gives us 0,2Volts, it's not here, we can't find it, what causes this, it is said that each and every component of the circuit has a resistance which we call internal resistance which is small, the conductors took 0.01, the ammeter also took its 0.01 even the resistor took 0.01 obviously by the time it gets there, there is something being used without permission. So that voltage that you will read on the Voltmeter even if there is no current flowing, we call that the emf of the cell but then the potential difference of the circuit is this one that we will finally read here (3.8V). Though emf of the cell is not in your syllabus for you to know what it means…

Thando‘s analogy of water pipe for electric current flow and electric circuit components was to simplify the process for epistemological access, as she linked with the target science concepts. It was interesting to observe that Thando uses IsiZulu language when describing the analogy and switches to English language when integrating the analogy into the scientific discourse. The teacher indicates the idea of little water that gets left behind the pipe as the same thing that applies when current is flowing in a circuit, that little water is linked to internal resistance. The teacher‘s use of code mixing represent the use of language coherently to ensure that the meaning of scientific concepts is not lost, at the same time develop learners‘ understanding of scientific concepts. Lehesvuori and Ametller (2021) posit that in the case of science education, knowledge construction takes place at the interplay between science language and connected activities in building science content. Thus, while communicative approaches focus on the managing of the teaching-learning process where language is the mediational tool of that activity, pedagogical link-making refers to both the process of meaning-making and the knowledge being constructed. Thando used a closed confirmatory authoritative communicative approach to narrate the analogy and links it to the target concepts, because she asked some questions that only required learners‘ confirmation with a yes answer while Thando responded to some of her questions through evaluation.

Thando‘s analogy of 25 litres of water being poured into one end of a pipe and then getting 24 or 24.5 litres on the other end of the pipe, was linked with the target scientific concepts of emf and internal resistance while referring to Photograph 65 where 4Volts is placed at the power source the electric circuit open. The teacher was conscious of her CSA and content relating to Grade 10 because she only mentioned internal resistance while it was not focussed on, since it is not discussed at this grade yet. From the VSRI Thando mentioned that ―according to the syllabus, emf is treated the same as potential difference but I just wanted them to know that these two are different because they will be different when they learn them in Grade 12‖.

Similarly, for emf, which is not discussed in detailed at this grade, Thando acknowledged this curricular limitation to learners and explained why she is only referring to emf to promote concept continuity which involves ‗recovering‘ points of view raised in earlier lessons and further developing them or setting out the agenda for what is to be worked on in future lessons (Scott et al., 2011). Therefore, the importance of emf was linked to differentiate between emf and potential difference and the teacher maintained this difference. This discussion was picked up again in lesson 2, episode 1, when Thando presented electric circuit components in relation to emf and potential difference. It was further important to show learners that learning scientific conceptual knowledge involved recognising how the scientific concepts fit together in an interlinking system (Scott et al., 2011), when Thando moved from Photograph 64 (closed circuit) with 4Volts (emf) and referred to Photograph 65 (open circuit) and placed 3.8Volts (potential difference). The difference between 4V and 3.8V was 0.2V, which Thando classified as lost Volts and linked it to the little water that was left behind in the water-pipe analogy. The pipe-analogy was selected and used for its relevance and potential to stimulate good understanding of internal resistance and because of its familiarity with almost all learners, Thando alluded during the VSRI.

Notwithstanding the importance of analogies used, I observed that the differences and similarities between the water-pipe and donkey-load analogies and target concepts were not explicitly discussed in the analogies. The ―Unshared attributes between analog and target are often a cause of misunderstanding for learners who attempt to transfer or map unshared attributes from the analog to target‖ (Dilber & Duzgun, 2008, p. 175). However, the used analogies provided good reference points for the teacher in talking about internal resistance and current flow in a circuit even though attributes of the analogue and target concepts were not shared for the development of deep understanding. Both the analogies of a water-pipe and donkey – load were selected for their relevance and potential to act as a kind of ‗memorable event' (Scott et al., 2011) considering that in the rural context of this teacher, donkeys are part of transportation, and the mountain referred to in the water-pipe analogy is across the school. Therefore, the analogies provided the teacher with representational structures of the abstract scientific concepts as the Thando also alluded in VSRI that both analogies assisted her to teach the abstract concepts of internal resistance and electric current. Though useful according to the teacher, her usage of both analogies could be strengthened by explicitly highlighting limitations of both analogies, and similarities and differences between the analogue and target concepts to promote deep understanding of scientific knowledge. The teacher ended the lesson by giving an application task for learners to do as homework and corrections were done in lesson 2, episode 2. In the following lesson, Thando focuses on emf and potential difference calculations.

8.2.2. Lesson 2: Electric circuit components and potential difference (emf)

Lesson 2, Episode 1

In this lesson, Thando connected the individual components of the electric circuit that were discussed in the previous lesson, showed learners each component and how they are individually connected in a circuit, and the role of each component in an electric circuit was re-enforced. The following teacher talk demonstrates,

> **Thando:** Today I brought you the different components of a circuit as you will see it being drawn…it will be better if you see science as we talk about it. Whenever we talk of a cell we talk about this (*showing a cell – Photograph 66*). We are used to calling it a battery at home but this is a cell, where there are two or more cells then we can call it a what, a battery. Okay then this is a cell holder…this is an instrument which is used to measure the current's flow within the circuit (Photograph 67) and we call it the what? [**Learners**: Ammeter] This is the ammeter and where it is red you put a connecting wire which is red and where it is black you put a negative terminal… Okay we've got this one (Photograph 68), it looks the same as this one but this one has got a V on it and this one is an ammeter has got an A on it, the difference between these two is that an ammeter measures the current and it is connected in? [**Learners**: series]. This one is measuring the what? The voltage and it is connected in? [**Learners**: parallel]. But if you look they all look the same, you would see when you are inside that this is V and this is A. Okay whenever you talk of a conductor, we are talking about these wires. And then this is the bulb, when it lights up you can see that there is current flowing in the certain circuit.


Photograph 66: A Cell


Photograph 67: Ammeter


Photograph 68: Voltmeter


Photograph 69: Voltmeter


Photograph 70: Electrical tool kit

Thando displayed her knowledge of curricular saliency (CSA) and conceptual teaching strategies (CTS), when she highlighted the Big ideas of Electricity topic and acknowledged part of the topic that are difficult to teach and/or learn (WDT/L). The teacher used macroscopic levels of representations (REP) to visualise the concepts and content. The REP‘s were used explicitly and relationally with LPK because Thando was aware that some concepts, like battery and cell are misused in the everyday life context and needed to be re-explained using demonstrations in a science classroom. Thando also drew from WDT/L when representing the ammeter and voltmeter at a macroscopic level.

The teacher continued to use closed confirmatory authoritative approach (CCA) and IRE in this part of the lesson, irrespective of most concepts being taught and explained earlier, and could have involved learners through meso-time scale to see whether and to what extent learners have comprehended the science knowledge. However, the teacher did not take anything for granted during the macroscopic level of representations through demonstrations in Photographs 66 – 70 as she constantly connected previous lesson‘s content and explained the roles of each demonstrated circuit components and their differences. To understand the reason for repetition and limited learners‘ involvement in this lesson, during the VSRI Thando said ―learners know these components, when you say switch, they know how to draw it maybe from Technology but they have never been in a lab to see what is what.‖ Therefore, for Thando, learners were to observe while the teacher talk and actions dominated.

From the episode, Thando further addressed the different way of explaining a cell and battery, ―We are used to calling it a battery at home but this is a cell‖ (Thando), where teaching involved making links to differentiate the scientific way of explaining from everyday views. The teacher was not addressing the misconceptions but also made learners aware of the scientific need to understand the differences in everyday talk and scientific talk. The teacher once again acknowledged what is difficult to teach and learn about the abstraction of current flow in a circuit hence the use of a familiar situation (light bulb glow) to explain a scientific concept and process (current flow), and this is commendable to ensure learners‘ understanding. After the demonstrations, Thando does corrections for the homework given in the previous lesson (lesson 1, episode 4) and re-emphasize the meanings of emf and potential difference in the following episode.

Lesson 2, Episode 2

In lesson 2, episode 2, Thando starts by analysing and solving learners' homework which was about addition of potential difference when cells are connected in series and when connected in parallel. A re-emphasis on the difference between emf and potential difference was observed in this episode, where links were made to the content of previous lessons under the concept of Electrostatics and potential difference. The excerpt below demonstrates,

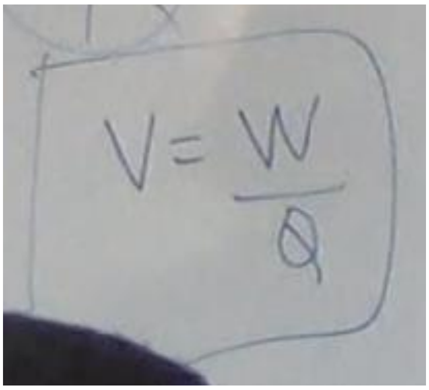
> **Thando**: … please open yesterday's work so that I can see if you added well. Exercise 14.1... Number 1, what is the value if each cell is 3V, what will be the total voltage in each of the batteries? [**Learners**: 3] 3 Volts, not just 3, if you just say 3, I don't know if you mean three chickens. Never leave a 3 without anything on it so you always put the what? The units so that you are correct, in science we never leave things without their units, are we clear? [**Learners**: yes] So what is the answer for number 1? [**Learners**: 3 Volts] 3 V, then number 2? [**Learners**: 6 Volts] Yes? [**Learner**: 3 Volts] 3 Volts , I explained to you that if they are connected in parallel the first one will be used before the other is used up so if you get the one value so it's 3V also and number 3? [**Learners**: 12 Volts] It's 12 Volts because they are connected in series so you have to add all of them and number 4? [**Learner** : 9 Volts] Number 4 is 9Volts. Number 5? [**Learners**: 6 Volts] Is it 6 Volts? [**Learners**: No] Yes it's not correct, what is the correct one? [**Learner**: 15 Volts] It's 15V because they are in parallel with the first one but with the other one it's also in series so you add 3, 6, 9 + 3x2 which is 6 so 9 + 6 give you what? [**Learners**: 15 Volts] So the correct one is 15 Volts you see? [**Learners**: Yes] Shall we move on? [**Learners**: Yes].
>
> **Thando**: … I just want us to discuss an important aspect that we called, yesterday we spoke about the emf of the cell right? and I explained that the emf will be the one that will give you the value that you will be given even if there is no current moving in the circuit and then there is potential difference, when the cell is switched on, then it will drop a bit and a few volts will be lost and the value that you will get there will be your potential difference, potential difference is V and V is measured in volts. Okay let me go through the explanation and explain what it means. A potential difference between two points in a charge is the change in electrical potential energy per unit charge. Potential is the energy that every object will have before it starts to do something, haven't you heard someone saying you have potential, it means you can do it. So potential energy is the energy that is possessed by all the objects that are not doing anything that are about to do something … Okay now potential difference is the work done over charge when they say the work done over charge, the definition says is the work done per unit charge to move a charge from one point to the other which means this charge we are talking about here is per unit, it's a singular charge by itself. So, when we say V= W/Q that's what we mean, it's just a definition for what, for potential difference (Photograph 71).

The episode included problem solving of the task about addition of potential difference when cells are connected in series and when connected in parallel, which learners were supposed to engage with, but Thando did all the corrections reading the answers from her textbook.

During the VSRI, Thando said ―I need to guide them to make sure they are doing calculations correctly. But then these were corrections so I had to guide them‖. Hence, the reason Thando did the work for the learners in this episode. Considering that the first part of the lesson focused on corrections of the work that was already taught and learners were expected to have engaged with it to show their understanding of the knowledge, it was expected for Thando to use the interactive/dialogic communicative approach. The teacher and learners could have explored the ideas together, led by learners and confirmed by the teacher, and work on different points of views as presented by the learners but the teacher took a leading role in the first part of the lesson.

The learners' prior knowledge (LPK) using the combination of meso—time scale and micro-time scale could have been used to develop the scientific story for the promotion of concepts continuity. Instead, Thando continued to use a non-interactive/dialogic approach, which played out through distinctive teacher initiation-response-feedback-evaluation- (I-R-F-E) patterns, which contradicted the purpose of the activity to support knowledge building and promote concept continuity through developing a scientific story. It was therefore difficult to conclude whether learners were able to engage with a task and understood the scientific calculations in relation to the content. I further observed that when learners gave incorrect answers Thando focused on solving the parallel connection first and then series connection in a complex circuit scenario thus focused on asking the final answers for each question and did not focus on learners' contents or procedural skills understanding for each question. It was interesting and concerning to observe that all the corrections were done verbally by the teacher and nothing written on the whiteboard.

In the second part of the lesson, Thando used a non-interactive/authoritative communicative approach by recapping on the difference between emf and potential difference, which she had explained in the previous lesson and episodes. The teacher used meso-time scale to make continuity link to develop a scientific story. The use of authoritative approach was to present facts and skills independently without showing the relationship between and perpetuates the scientific point of view from the teacher as an expert, irrespective of the information being repeated from the previous episode. While the information was important because Thando was explaining the meaning of the concepts, and represent the curricular saliency (CSA), only narration was used without writing the information on the chalkboard. In the VSRI, Thando explained that ―I needed to explain and remind them of emf and potential difference‖, and because of this explanation, Thando applied a non-interactive / authoritative communicative approach. I observed that Thando further explained potential difference from the textbook and connected with symbolic representation (Photograph 71) to link theory and calculations. This explanation is further analysed into electric circuits‘ context in the following episode 3.



Photograph 71: Potential difference equation

Lesson 2, Episode 3

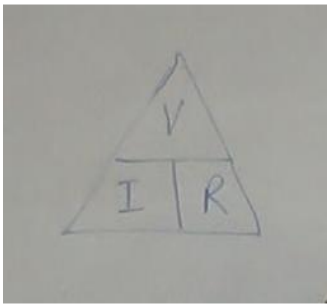
The explanation of potential difference as V=W/Q was further linked with the introduction of Ohm‘s Law and its symbolic representation (R=V/I). Recapping of previous concepts to link with the current concepts and processes was important for Thando, as she connected the concept of electric current, giving its mathematical interpretation (equation) and the concepts of voltage and resistance while moving towards a Big idea relating to Ohm‘s Law. Even though she was revisiting previous concepts, learners continued to complete Thando‘s sentences and answered her closed confirmatory questions following the initiation-response-evaluative-feedback (IREF) patterns, and interactive/authoritative communicative approach. The teacher talk demonstrates,

> **Thando**: Now let‘s move on to what we call current, when we talk about electricity we mean current, what is current? Electric current is the rate at which the charge flows, so the electric current is the rate of flow of charge so current, electric current is measured in Amperes. Okay current is said to be the current electricity it is (I) the thing… I is the symbol and it is measured in Amperes since here V=potential difference, V Volts here I must say, I is current and it is measured in what? [**Learners**: A] A for what? [**Learners**: For Amperes]. Okay now, the electric current is the charge that is passing over time that is taken, so I equals to the charge that is passing over time taken so it‘s *C* over *S* it is equal to time. Now, yesterday I spoke about conventional current as the movement of current from positive to negative terminal. To measure the current in a terminal we use the what? We use the ammeter; it has got A connected in a circuit in a what? In a series. Okay and then there is … resistance, by a resistance we mean the ratio of the potential difference across the electrical component to the

current. Now the ratio between the potential difference which is V and the current (I) will give you the what? [**Learners**: The resistance] Resistance is measured in what? In Ohms and this is how we write it (as she write Omega sign on the chalkboard - Ω), so the ratio has got the what? The current.

Thando: Now I want to tell you about the relationship between these three, now look, stop writing because when you are home you won‘t be able to explain what it is you were writing. This is what I mean, I am drawing a triangle with a T (*referring to Photograph 72*). For these three (*symbols in Photograph 72*), whatever that I want, I will press it by a thumb, so when we want to calculate I, we are given V and R and want to calculate I what do I do? Cover with a thumb, right? so we get I equals to, is there anything on top? [**Learners**: yes] which is? [**Learners**: V] So we have I = V and place a division line beneath V and below there‘s? [**Learners**: R] Then No. 4? I want R, I have covered it, so my R is equal to, is there anything on top? [**Learners**: yes] which is? [**Learners**: V] Then over what? [**Learners**: I] Then I want to calculate V now, let me write the V, is there anything on top? [**Learners**: _no‘] you see? So, everything is on the bottom, it‘s going to be _I times R‘ (*teacher writes all the three manipulated equations on the whiteboard - I = V/R; R =V/I; and V= IR*)

As noted from the above teacher talk, Thando has been _telling‘ learners about the Electricity topic, and instructing them to pay attention to what she identified as the Big idea and understood as what is difficult to teach and learn (WDT/L) and need teacher‘s curricular saliency (CSA). The use of symbolic representations (REP) was important in this lesson as Thando makes an explicit between scientific concepts of current, voltage, and resistance. The teacher explained the idea of movement of current including its measurement and connection of an ammeter in a circuit, which was further linked with the idea of resistance. Thando knew how to draw learners‘ attention to important information as she explicitly stated the interrelated concepts of resistance, current and potential difference. The interrelationship between scientific concepts was explained through Photograph 72. Using the same photograph, Thando engaged with the procedural skills needed by learners in manipulating the V, I, and R equation, such as hiding the unknown component by thumb and being left with either V=**IR** or I=**V/R** or R=**V/I** when using the referred picture. During VSRI, Thando mentioned that ―Learners need to write DATA, because *uma engayibhalanga* (if they have not written it), they just make a mess. They must first see what is given and what is asked so that they know, which formula must I use‖. This practice demonstrated teacher‘s awareness of learners‘ difficulties with calculations hence a conceptual teaching strategy of writing DATA first and/or hiding what you are given from the equations.



Photograph 72: Ohm‘s Law representation

It was interesting yet concerning to observe that irrespective of the concepts being taught and explained in the previous lesson and episodes (LPK), Thando emphasised on their meanings (CSA) as she continued to re-explain them linking with the current lesson, however, without learners‘ participation. Instead, the teacher used limited interactive/authoritative approach which is demonstrated through teacher‘s initiation-response-evaluation (IRE). This episode was followed by practical examples where Thando guided learners on how to apply the procedural skills that were taught above.

Lesson 2, Episode 4

Thando read the exemplary question to be solved, and analysed the question to simplify it while emphasising the important given data, especially the unknown (potential difference) which is to be calculated in this problem solving using equations in Photographs 71 and 72 in the previous episodes 2 and 3 of the current lesson.

> **Thando**: Okay let us do the first one to calculate the potential difference across a battery if 3 C of charge gave 27 J of energy passing through it, calculate the what? The potential difference, if what? It is said if 3 C of charge gave 27 J of energy, it means charge is 3 C and energy gained or energy transferred is 27 J. The first thing you do is the same as what I taught you to do when you were doing the waves, do you remember that? [**Learners**: yes] The first thing you do, what do you write? The data you are given, what do you have? It is said to calculate the potential difference so what is unknown? [**Learners**: potential difference] Potential difference, which one is potential difference on the board? [**Learners**: It‘s V] So, my V is unknown right? [**Learners**: yes] What am I given? Charge and it is what, 3 Coulombs. What else am I given? Energy transferred, if we say energy transferred, what do we mean by that? [**Learners**: work done] Work done right, and my work done is what? [**Leaners**: 27 J] I said that work done is equal to the energy transferred, I will start by placing my formula V= W/Q…The work done here is? [**Learners**: 27] Over the charge, the charge is 3 C and the answer is? 27 divided by 3? [**Learners**: 9] 9 what? [**Learners**: Volts]. … Calculate the current in a length of a wire if its resistance is 5 Ohms, now we write our given data, the resistance is 5 ohm and the potential difference is 20 volts, calculate what? The current. What is the formula? [**Learners**: I] I is equal to? [**Learners**: V/R] V/R and V is equal to? [**Learners**: 20] During calculations you can leave out the unit but when you get to the

final answer you must use it. And your R is? [**Learners**: 5] And your answer is? [**Learners**: 4] 4 what? [**Learners**: Amperes] Amperes. Never leave your answer without units…

It is difficult to ignore that Thando continued to do the work for the learners, while she was dominantly reiterating the work that was done in previous lessons. The implications are that learners‗ lack of frequent and more meaningful interactions on cognitive tasks will lead to learners‗ poor performance (Manion & Alexander, 1997). The teacher revised and taught learners understanding of what was done already, she continued to use tasks to teach scientific ways of communication, SI Units in the final answer. Also, Thando did not only make links to the work that was covered in the previous lessons, but continued to induct and coach learners about writing the given DATA sets first before doing the mathematical calculation. When she was asked about this in the VSRI, Thando said ―bona bayakhuluma (they speak) in class but they make mistakes with calculations, they need guidance‖. Again, Thando solved the problems while learners‗ participation was through retelling the given values from the problem solving question, including mathematically calculating the values placed by the teacher on the equation. Through this practice, Thando refers to learner prior knowledge but does not draw from it or solicit the understanding from learners. Also, the symbolic REP for work done is applied on an abstract explanation of work done. In this section of the episode, Thando seems to be interested with the use of a correct equation, correct substitution without meaning-making through calculations. This practice followed a mixture of evaluative / authoritative; and feedback / authoritative (IRE-IREF) communicative approaches.

Interestingly, Thando used this episode to re-emphasise the importance of always using SI Units in the final answer (CSA), while she advised learners not to use units in the calculation steps. SI Units are important in science and science teaching because without them, the calculated answer has no meaning. So SI Units contextualise calculations. Thando‗s classroom practices showed the dominance of initiation – response – question – response (IRQR) pattern, because she was authoritative during all lesson episodes while learners completed her sentences and responses. The teacher used the task in this episode to conclude the lesson. From the teaching approaches, Thando used multifaceted approaches as she could also be critiqued as ‗teaching for her own learning‗ and ‗learning for the learners‗, because she did most work for them.

This lesson 2 has macroscopically represented the electric circuit components; electric current was explained including its movement in a circuit; a link was made between current, voltage and resistance leading to Ohm‘s Law relation at the end of this lesson. A task relating potential difference to work done per unit of charge (V=W/Q), and potential difference with electric current and resistance (V=IR) was given to learners even though the teacher did the tasks for learners. In the following lesson, Thando focuses more on series and parallel circuit connections and the calculations associated with these connections. Of importance with this lesson is the diagrammatic representation of series and parallel circuits including the differentiation between the two circuit connections.

8.2.3. Lesson 3: Series and parallel electric circuit connection

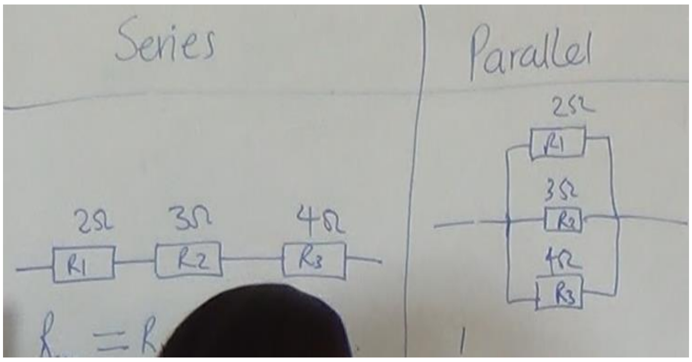
Lesson 3, Episode 1

In this lesson, Thando symbolically connected the series and parallel resistors to demonstrate their connectivity in electric circuits but only explained as resistor connection without being placed in the electric circuits diagrams. Also, calculations of resistance, voltage and current in the circuits were emphasised in this lesson. To introduce the theoretical connectivity of resistors, Thando links the connection of cells from lesson 2, episode 2 with the connection of resistors and differentiates between series and parallel resistor connection through a use of diagrams drawn on the whiteboard in Photograph 73. The following extract indicates,

> **Thando**: we are still going to do the circuits and I can promise you that even your test, your practical test that you are going to be writing, you will be writing it based on these circuits and in order for me to give you the mark you will have to touch this (*Points to the circuit components on her desk*) you will have to light and explain that it‘s like this and that and then they will light with your group so don‘t worry about this thinking that you will only look at them, you will touch them and do it so it‘s fine. Don‘t worry about it for now, we are going to do it later in our practical time.

> **Thando**: There are two ways in which you can connect a circuit, we did the method of parallel and series, we looked at it when we were doing what? The cell connection remember? [**Learners**: yes] And I said if the cell is connected in series you have to add up all the cells that are there, that is a series connection but when they are connected in parallel, first one has to be finished before the second one starts to work right? [**Learners**: yes] But now we are looking at the resistance connection, now resistors can be connected in two ways, there is the series connection and then the parallel connection, okay. Then in series connection … whenever I explain something and at the time you are writing, I always say to people that when I explain I want you to listen to me carefully and take notes so that when you write, you write seamlessly... Let‘s talk about 3 series connection, R_1, R_2, R_3 and then here we have got (*Draws on the board*) R_1, R_2, R_3 but they are all connected in different connection so this one

(*left hand side of Photograph 73-series*) is called the series connection because even the connection as you can see, they follow one another so they are in series, serial and this one (*right hand side of Photograph 73-parallel*) is the other one on top of the other so then they are in parallel.



Photograph 73: Demonstration of Series and Parallel resistor connection

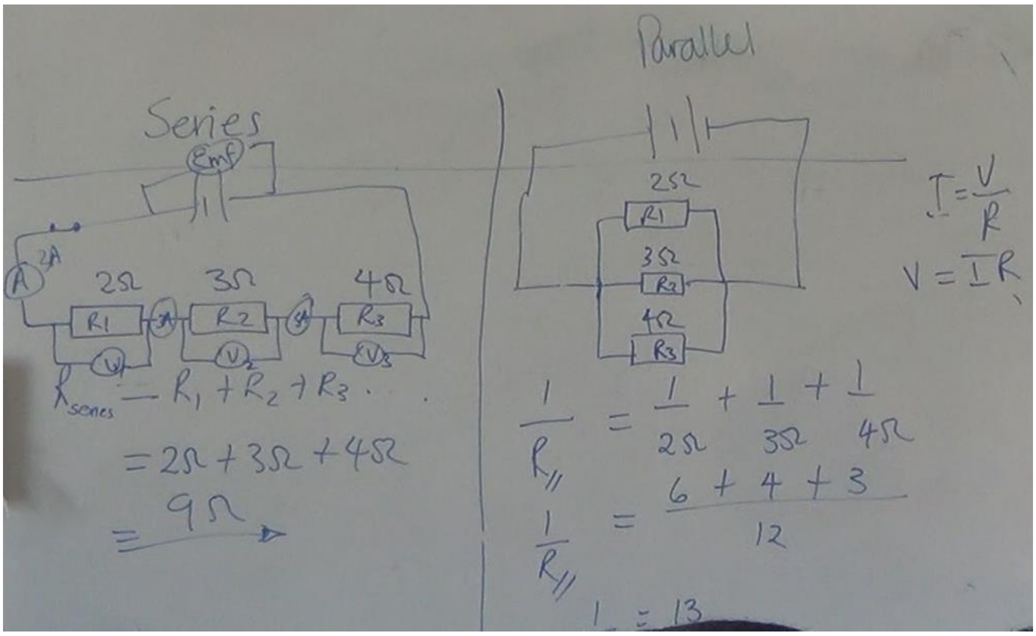
Thando made learners aware of the assessment expectations for practical test, and emphasised that learners ―will have to touch this‖ (*points to the circuit components in the toolkit on Photograph 70*). She assured learners that they will do practical activities later in group form, because the focus of the lessons has been theoretical and laid the content and concepts foundations for the practical aspects which were not carried through during the duration of data collection for this study. The lack of practical work for this topic denied learners the practical skills needed in working with electric circuits. Also, most aspects of electric circuits are abstract and the use of practical work could help learners develop a deep understanding of current, voltage and resistance including the idea of ―on‖ and ―off‖ of a switch. Thando further acknowledged the importance of electric circuit connection, without demonstrating to the learners how the electric circuit connections are done. This showed teachers‘ awareness of curriculum (CSA) as it prioritises electric circuit connections and views it as an important teaching and learning tool in Grade 10. Furthermore, Thando constantly repeated the meaning of series and parallel concepts and their relationship to develop deep understanding of a scientific story. The teacher drew on Photograph 73 to make a link to differentiate between resistors connected in series and those connected in parallel. There was modelling of the physical processes of the phenomena such as demonstrating the connection of 3 resistors in series and in parallel as the teacher made a link to differentiate between the concept of series and parallel. Teacher dominated the classroom talk and this section of the lesson was non-interactive / authoritative.

Furthermore, the persistent reminder to listen and focus on the lesson represents teacher‘s awareness of the difficulty of the topic. The lesson continued to be teacher centred and authoritative, because the interaction with learners was limited to the approval of teacher‘s statement. It was interesting that in the previous lesson, Thando discouraged learners to take notes while she was teaching and instructed that they listen carefully to what she was saying, in this lessons she insisted that learners continue to listen carefully and take notes. Moreover, the teacher linked theoretical explanation of series and parallel resistors including the symbolic representation in Photograph 73 to the scientific problem solving through symbolic representations (equations) in episode 2 of this lesson.

Lesson 3, Episode 2

In the episode 2 of this lesson, Thando linked the drawn resistors diagrams in Photograph 73 with the calculations of resistance associated with both series resistors and parallel resistors. In this episode, the teacher moves between the diagrammatic mode of representation to symbolic representation (equations). Also, Thando made a linked to differentiate the use of Ohm‘s Law equation done in lesson 2, episode 3 with the calculation of equivalent resistance in series and parallel circuit connection. The extract below demonstrates,

> **Thando:** Now when you are connecting the resistors in series, you must know how to calculate the equivalent resistance… I just want to know the resistance, we know the resistance is (*points to series side of Photograph 73*), this is 2 Ohms, this is 3 Ohms, and this is? [**Learners**: 4 Ohms] (t*eacher points to the parallel side of Photograph 73*) this is 2 Ohms, this is 3 Ohms, and this is 4 Ohms. So, these resistors are the same it‘s just that these ones (*left hand side of Photograph 73*) are in series and these ones (*right hand side of Photograph 73*) are in [**Learners**: Parallel]. The important aspect here is that when you calculate the resistance you use I=V/R but now you can‘t use I=V/R without knowing R, because R you have to calculate the available resistance in a circuit, … a particular circuit here, it has two cells, there is a certain resistance and there are three resistances formed in a particular way and then we‘ve got (*draws a complete circuits in Photograph 74*).



Photograph 74: Series and Parallel circuits

Thando: I then said that when we talk of the current, some of the current will be resisted, all the connectors will resist, the ammeters, they are all going to take something that we call internal resistance, are we clear? [**Learners**: Yes]. Remember when I explained and said that its internal theft, we call that internal resistance and then this other one from the resistors we call it external resistance, we call it R-external. And internal resistance is symbolized by [**Learners**: Small r]. Internal resistance and external resistance will always give us the total but since we are not going to calculate internal resistance, we are only going to look at this resistance (*external resistance*) which is provided by the resistors…so whenever you calculate this resistance (*points to series resistors*) you don‘t call it total resistance, you call it equivalent resistance or external resistance, we call it external but other books refer to it as equivalent resistance. So here if you are adding the resistance that are connected in series you say R_{series} equals to $R_1 + R_2 + R_3$… which means that it depends on how many there are, if there are 10, it‘s + R_4 + R_5 until you get to 10. So in this case it will be what? [**Learners**: 2 Ohms + 3 Ohms + 4 Ohms] And that will be how many Ohms? [**Learners**: 9 Ohms]. See how we calculate resistance? [**Learners**: Yes]. Let‘s go to the one in parallel, how do we calculate here? Where it‘s parallel, it is not just parallel, it will be $1/R_{parallel}$ = ½ Ohms + 1/3 Ohms +1/4 Ohms which are equal to? $1/R_{parallel}$ = then you look for lowest common denominator, which is what? [Learners: 12] (*teacher writes 12 below division line and final answer)*

To perform conceptual demonstrations of connecting three resistors in series and parallel electric circuit, Thando used symbolic representations and whiteboard, to symbolically show learners the components of a circuit and how they are connected in a diagrammatic electric circuit on the board. It was important for the teacher to connect the symbolic and diagrammatic representations because scientific concepts are articulated across these media of representations and it is only in the integration of these various aspects of REP‘s that the whole concept exists (Lemke, 2000). Interestingly, the reiterations were also used for self-check and for confirmation of teacher knowledge rather than checking learners‘ understanding of what has been said or done. Thus, Thando made pedagogical links between scientific concepts (internal, external resistance, current, and voltage) and their sequencing and also moved between different scales and levels of explanation and representation, and further differentiated between total resistance and equivalent resistance or external resistance. The teacher also guided learners on how to apply the resistance equations: $R_{series} = R_1 + R_2 + R_3$… and $1/R_{parallel} = 1/R_1 + 1/R_2 + 1/R_3$ in solving for external resistance for both series and parallel circuits. In the VSRI Thando explained that ―It is better for me when I do it simultaneously because it is about comparing. This side is 1/R and here is $R_1 + R_2$. It‘s about camparison.‖ Thando‘s conceptual teaching strategy demonstrates her acknowledgement of what may be difficult for learners to learn even though learner prior knowledge was not solicited to determine the level of difficulty of working with series and parallel resistor equations (symbolic REP). This practice demonstrated Thando‘s evaluative authoritative communicative approach.

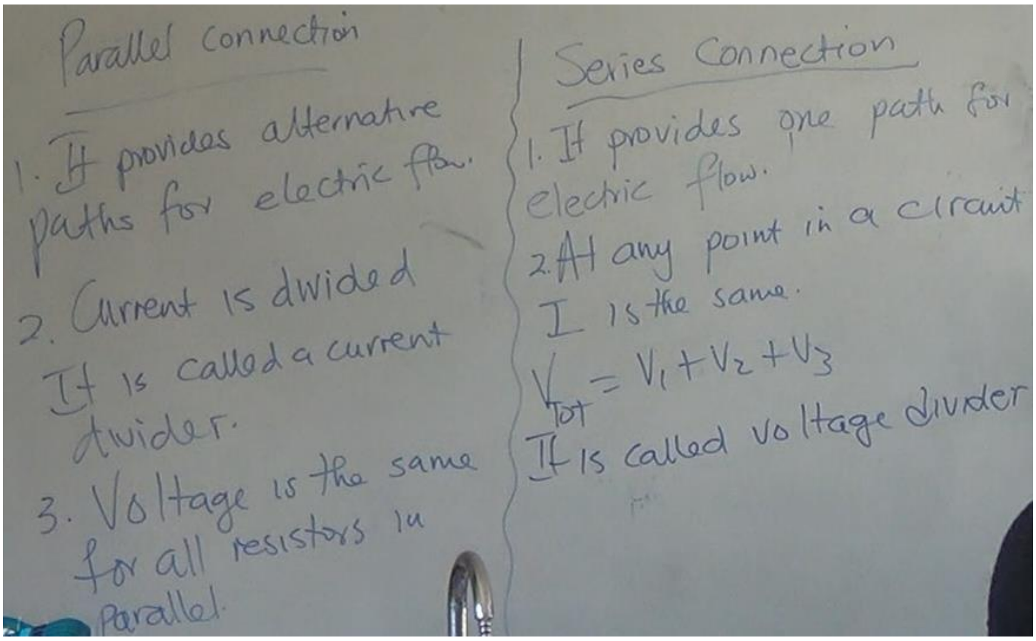
Moreover, Thando made a link to differentiate between Ohm‘s Law (I=V/R); $R_{series} = R_1 + R_2 + R_3$… and $1/R_{parallel}$ = ½ Ohms + 1/3 Ohms +1/4 Ohms ($1/R_{parallel} = 1/R_1 + 1/R_2 + 1/R_3$) and wrote all three equations on the board as indicated in Photograph 74. Also, diagrams were used by Thando to further make the link to differentiate between series and parallel circuit connection as demonstrated in Photograph 74. She emphasised the idea of resistance noticed through her use of Ohm‘s Law equation focussing on R (resistance). The meso-time scale played a crucial role to link the concept of resistance in a circuit with this episode. Thando made an important link to differentiate between internal resistance and the external resistance, which represented curricular saliency when emphasising that learners would learn about internal resistance in the subsequent grades, especially Grade 12. This practice also addresses macro-time scale continuity link-making, because the teacher links the current to future content for science story development and continuity. It was interesting how Thando linked the calculation for resistance in series circuit connection and calculation for resistance in parallel circuit connection by writing each equation and calculation under respective circuit connection as shown in Photograph 74. After showing the difference between series and parallel circuit connection through diagrams, it was important for Thando to conceptually explain the differences between the series and parallel circuit connections. The following episode 3 demonstrates this explanation.

Lesson 3, Episode 3

In episode 3, Thando continued to make links to differentiate between the series and parallel resistor connection while also describing each connection path. The following excerpt demonstrates,

> **Thando**: The parallel connection provides different paths for Electricity, if it did not go through here, it can get here and split, one goes this way, one goes this way and the other goes this way but still they will meet up ahead (*referring to parallel resistor connection in Photograph 73*). It provides different paths, which means once this bulb bursts, the others will still work, this is why we use these at home because if the mother wants to sleep in her room, she can switch off the light but it will not switch off for other rooms because we have used parallel connection but if we were to use series connection when the father decides to switch off the lights, everyone will be left in the dark. Now let us talk about series connection, when we talk of series connection we mean firstly that it provides one path for electric flow meaning there is no other way to pass. Secondly if you take an ammeter and place it here, the value that you will find here, if it was 3Amps at the first position, even the second position will be 3Amps at any point because there is no other way for current to flow, it only flows through here so I mean at any point in the circuit, current which is I is the same...

> **Thando**: Now let‘s talk about the voltage, see? Let‘s talk about the voltage. We said it‘s emf here. We get it when what has happened? If maybe the switch is open and when it‘s closed? okay now if we talk about emf here and then talk about V, If I measure V here (*across R_1*) another V here (*across R_2*) and another V here (*across R_3*), so then the total voltage will be = $V_1 + V_2 + V_3$ which means that when the voltage gets here, it has to divide itself so that it works for this resistor (R_1), for this resistor (R_2) and also for this resistor (R_3), are we clear? [**Learners**: Yes] **Teacher:** … Series connection provides one path, parallel provides multiple paths. Series connection at any point in the circuit, current is the same with parallel connection Voltage is the same for all resistors. Series connection it‘s the Voltage divider and parallel connection, current divider… so that is the difference of the two.



Photograph 75: Tabulated differences between series and parallel connection

The main aim of this episode was to explain and link electric current and voltage, particularly in the context of series and parallel electric circuits, which was dominated by symbolic representations and demonstrations including tabulation. The teacher made a link to differentiate between the series and parallel connection through tabulation (Photograph 75) while making constant reference to the diagrammatic drawings of both series and parallel circuit connection in Photograph 74 in the previous episode. Thando‘s interchangeable use of Electricity and electric flow for a charge flow (current) made it unclear what uses the path provided by series or parallel connections. The teacher moved between explaining theory and drawn diagram (Photograph 73), and further linked these explanations to symbolic representations and real-world applications of each connection. The use of real-world phenomena – mother and father switching off the lights was used as an example for the parallel connection to promote deep understanding parallel connection. Thando demonstrated that the phenomena is not restricted to classroom or laboratory but happens in everyday home context, which brings science to life connecting it to the environment and to society (Treagust, 2007). As noted in this episode, the teacher dominantly used the non-interactive and authoritative communicate approach, irrespective of repeating the information she taught in previous lessons and episodes, and learners continued to confirm teacher‘s point of view.

After the explanation in this episode, the teacher ended the lesson by giving a classroom activity where learners had to apply knowledge and skills about the concepts of parallel and series circuit connection, especially resistance in each connection. The activity required the application of taught knowledge and skills. The activity was characterized by symbolic representations (equations) specific to series and parallel connections. Of concern, these symbolic representations were not written down but verbally communicated by the teacher. There were increased teacher-learner interactions. Of concern however, when learners had given their responses, the teacher did not provide feedback but would continue with problem solving assuming the correctness of learner responses though this is not communicated by the teacher, as she pointed out during VSRI. This teaching approach led to the teacher presenting a particular point of view where learners were only involved to confirm teacher‘s point rather than exposing their understanding of problem solving procedures involving series and parallel resistors. While monitoring learner solutions to problem solving, Thando re-emphasised the importance of including units in calculations. Moreover, there was also coaching of learners on how to approach problem solving involving complex circuit, where the teacher emphasised solving a parallel branch first to make the entire circuit a series connection then add all resistance of resistors in series. Thando continued with problem solving for electric circuits and the following lesson four details the problem solving initiated by the teacher during the lesson.

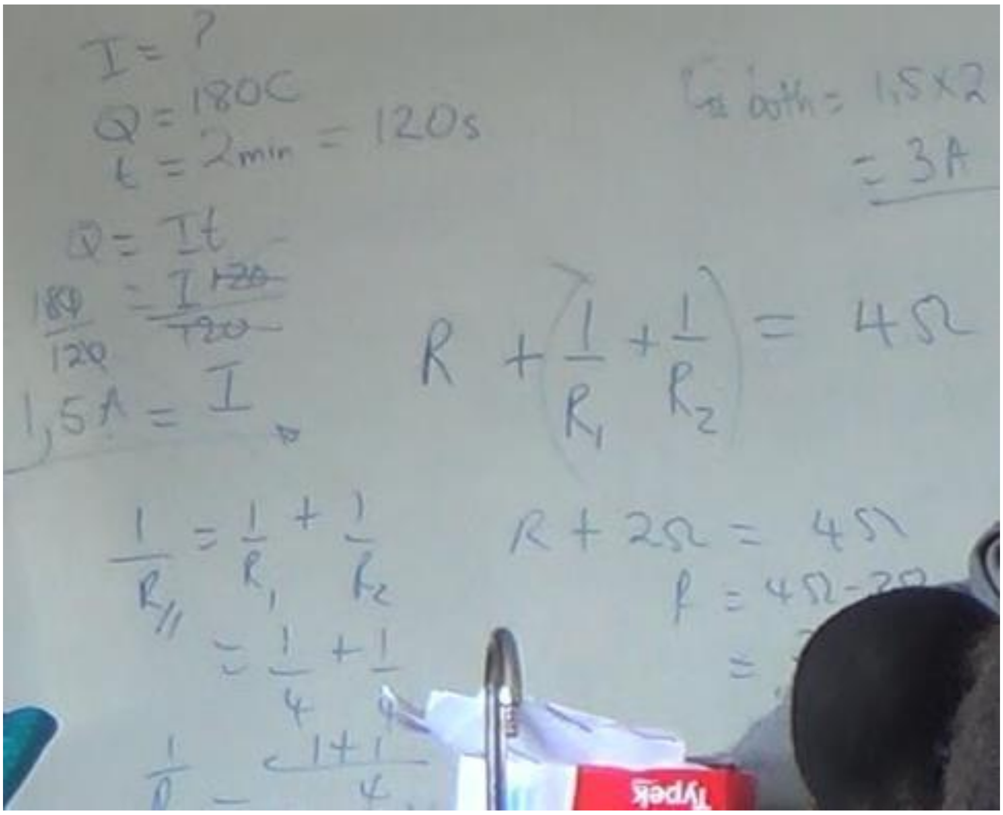
8.2.4. Lesson 4: Problem solving for series and parallel electric circuits

Lesson 4, Episode 1

The episode focuses on the classroom-based application calculations for series and parallel circuit connections. The classroom activity was teacher-centred despite questioning content knowledge and skills that were taught by the teacher. The teacher read from the textbook and referred to questions and diagrams from the textbook as she reads. The following excerpt illustrates,

> **Thando**: …there are two resistors that are connected in parallel, do you see those resistors? Each of them is 4 Ohms, … the question, it states calculate the reading on the ammeter if 180 Coulombs of charge passed through. Can you hear me? [**Learners**: yes] We have calculated the current but this current that we have calculated only passes on through one resistor and it‘s the 4 Ohms one which means the other ones we haven‘t calculated right? [**Learners**: yes] But remember that a 4 Ohm resistor and a 4 Ohm resistor are the same in resistance because they are both 4 Ohms resistors. So, 4 Ohm resistor at the top and one at the bottom. So if it is 1.5 Amps that gets there *(referring to the first 4 Ohm resistor)*, you remember yesterday I said to you, more current will go to the one with the lesser resistor but this time the resistors are the same. So what does that mean? It means the current flow will be the same. So if the first 4

at the top takes up 1.5, how much will the others each take [**Learners**: 1.5) Also so because it was said to calculate how much it will be on each, it means if this (*points to 1.5A in Photograph 76*) is what you get on each, this means if there are two (*Writes down on board*) it will be 1.5 times 2 that will be what? [**Learners**: 3] Amperes, we don‘t just say 3, I am warning you, no units in science, no marks, you will lose the mark of the answer if your answer does not have a unit.



Photograph 76: Teacher calculations on the whiteboard

The episode is a continuation of lesson 3 for electric circuit calculations. The teacher focused on the mathematical relation of current flow, voltage and resistance in a parallel circuit. This demonstrates the maintaining of the development of the scientific story through application of symbolic representations and link making between the electric circuit diagrams on Photograph 74 and calculations. The teacher read the questions, analysed it, planned how to solve it, and ultimately solved all questions while involving learners in the calculation of the final answer. Like in the previous episodes, Thando re-emphasised the importance of writing scientifically, with SI Units inserted when writing the final answer of a problem solving (CSA). It was interesting to observe the teacher making a meso-scale time link when alluding to the inverse proportionality link between current and resistance. Moreover, in the episode, Thando provided occasional hints to the asked questions and often simplified the questions for learners to understand.

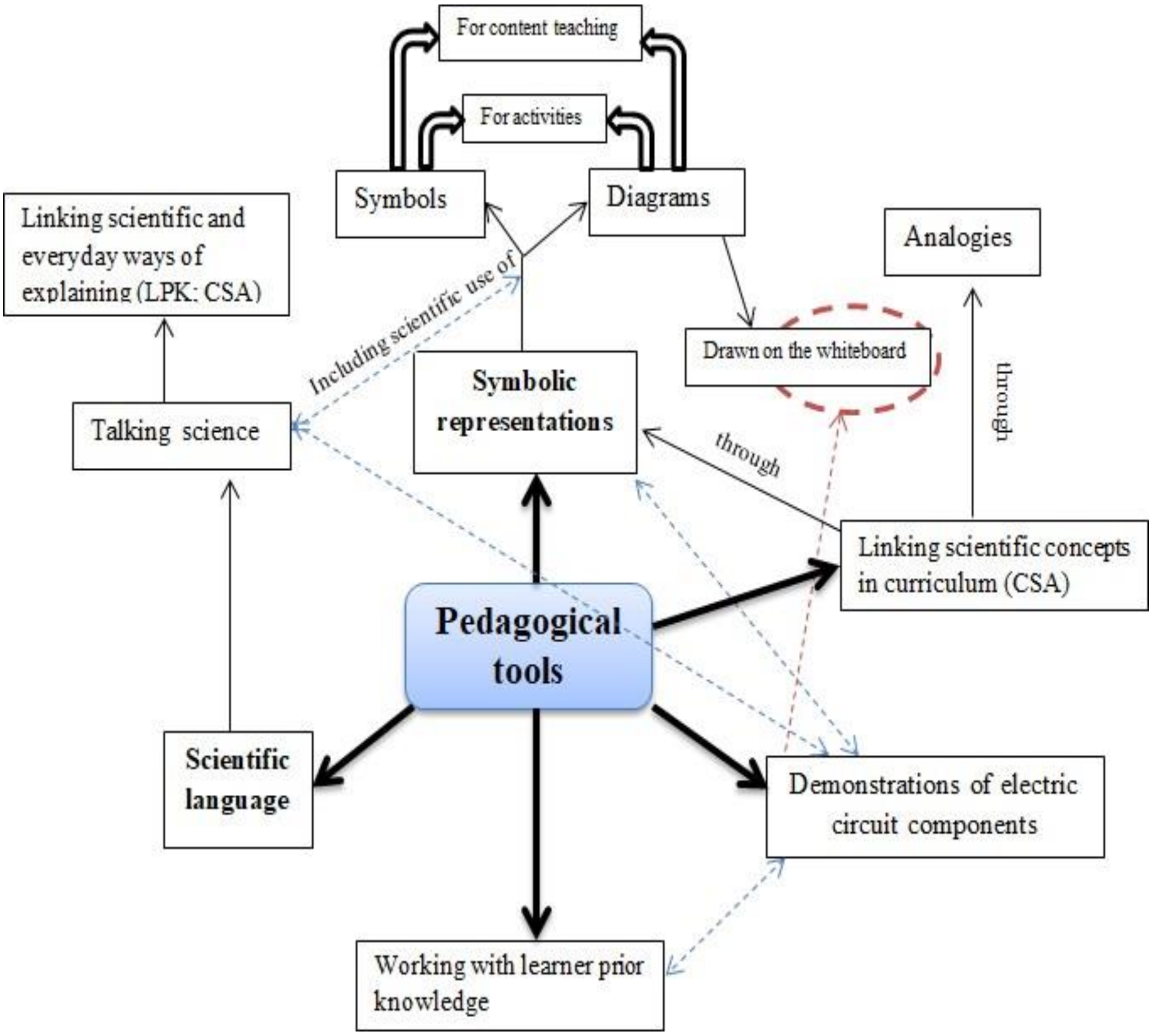
After classroom activity was solved by the teacher, she gave homework with questions from a previous Grade 10 June examination paper. With this activity, teacher trains learners for examination. The teacher emphasised mark allocation per question in the examination question paper to draw learners' attention to the importance of the Electricity section examined at Grade 10. Thando drew from learner prior knowledge when making examples of concepts (Ohm and definitions of Electricity terms) and content skills (relation between current, voltage, and resistance) required by learners. The teacher made a link between scientific concepts and their sequencing to develop a scientific story. Additionally, issues relating to curricular saliency were also demonstrated through summing up the taught scientific concepts. Also, scientific writing was encouraged in this section of the lesson when the teacher reiterated the need to be able to do or to think things scientifically. This section marked the end of the fourth lesson for Thando.

8.3. Chapter summary

The chapter has presented, explained, and analysed Thando's enacted pedagogical content knowledge of Electricity topic and her pedagogical reasoning that influenced her observed pedagogical practices of Electricity topic. Classroom observation and video stimulated recall interview data sets informed the analysis in this chapter. Emerging from the analysis, Thando's teaching was largely content-centred and learner-centred. The teacher made use mostly of analogical link-making, symbolic including diagrammatic representations which were all written and drawn on the whiteboard; macroscopic representations were used to demonstrate the electric circuit components; and references were also made to sub-microscopic behaviour of concepts taught. There were instances of teaching for examination. These tools were not linearly used but used interactively. Of these tools, symbolic representations (equations and diagrams) and analogies were dominant in the observed lessons while Electricity concepts and processes were barely represented at macroscopic and sub-microscopic levels of representation. Figure 11 below represents the complex nature of pedagogical tools used by Thando and the interrelationship between these tools as used in the classroom.

Figure 11

Teacher Thando's pedagogical tools used during the Electricity lessons



Thando developed a scientific story by constantly making links between the various pedagogical tools used, especially linking symbols (equations) with drawn diagrams and analogies. Constant links to work done within the lessons and across lessons was used by Thando to develop her scientific story further to help learners comprehend what she perceived as difficult for learners to understand (WDT/L). These links were justified in VSRI as important for formation and continuity of concepts within Electricity topic and across curricular (CSA). The following chapter discusses the findings from each teacher focussing on individual analysis and then interwoven analysis. Therefore, the following discussion is in relation to the identified framework in chapters 3 and 5, and also informed by the purpose of this study.

CHAPTER 9

A Cross-Case Analysis of teachers' pedagogical approaches in Electricity topic: Discussion of Findings

9.1. Introduction

In chapter‘s six to eight, I detailed each teacher‘s analysis of classroom observation practices; video stimulated recall interviews with each teacher to understand their pedagogical reasoning; and individual semi-structured interviews for their perceptions of science teaching. This chapter presents and discusses findings on teachers‘ approaches that emerged from the participants‘ classroom observable actions, reflective comments during VSRI with respect to their teaching of Electricity topic in rural classrooms and their responses during semi-structured individual interviews. This study used Mavhunga‘s (2012) topic specific pedagogical content knowledge (tsPCK) and Scott et al.‘s (2011) pedagogical link-making (PLM) as frameworks to understand teachers‘ pedagogical approaches for the Electricity topic. To complement the theoretical and conceptual frameworks, Mortimer and Scott‘s (2003) communicative approaches and patterns of Discourse were also used in the analytical framework to make sense of teachers‘ classroom practices. The theories and analytical framework guided the process of theme identification, resulting to the emerging themes to help answer the following research questions of this study:

1. What are the Grade 10 physical science teachers‘ pedagogical approaches during the Electricity lessons?
2. What are teachers‘ pedagogical reasoning for the observed pedagogical approaches during the Electricity topic lessons?
3. What are the factors that influence the teachers‘ pedagogical approaches to the Electricity topic in Grade 10 science classrooms?

To answer the above research questions, three themes emerged from the detailed analysis of three case studies using tsPCK, PLM, and communicative approaches (CA) including patterns of discourse as analytical frameworks. Table 17 below presents the summary of the themes that emerged from the data analysis processes. Thereafter, each theme and sub-themes are discussed in detail.

Table 17

Summary of themes and their focus

Theme	**Sub-themes**	**Focus**
Teachers pedagogical approaches to Electricity topic	i. *The symbolic nature of Electricity topic: Using different modes of representations and analogies to teach Electricity* ii. *Importance of supporting Electricity topic knowledge building* iii. *The role of practical work in the development of learners' scientific knowledge building*	The theme discusses dominant approaches from all teachers with the focus on the nature of explanations according to PLM's 6 Approaches for link-making for knowledge building and link-making for continuity. The theme also draws on the 5 components of tsPCK for teaching the Electricity topic and its related concepts. The intended and observable use of practical work to promote deep understanding for Electricity topic also featured in the classroom observation, VSRI, and semi-structured interviews. The use of analogies and representations to explain concepts relatively and relationally was dominant from all three teachers. I therefore focus on how teachers used pedagogical approaches to support knowledge building and promote concept continuity for Electricity topic.
Teaching Electricity topic and concepts for teachers' own learning.	i. Closed evaluative and feedback authoritative communicative approaches. ii. Initiation-Response-Confirmatory (IRC) approach	The theme focuses on dominant communicative approaches and patterns of discourse which as a result of teachers' observable pedagogical approaches. Teachers asked and answered their own questions; IRE/IRF for themselves; non-interactive/authoritative and evaluative authoritative communication approaches – which represent that they were teaching for themselves. Therefore classroom data from all three teachers suggested communicative approaches and patterns of discourse beyond those already in literature, hence the importance of this theme.

Factors that shape rural teachers‛ pedagogical approaches	i. Rurality and practical work at loggerheads ii. Teaching for assessment: Assessment-driven pedagogy	The theme focuses on the factors that influenced the evident teaching approaches. Various factors were alluded to by teachers during the VRSI, semi-structured interviews, and those observable during classroom teaching.

9.2. Teachers pedagogical approaches to Electricity topic

The pedagogical approaches teachers used in the physical science classrooms are important because they determine the nature of learners‛ participation or lack thereof, and also the ability to internalise the scientific knowledge for comprehension. Three sub-themes emerged from the analysed cases, which are: *The symbolic nature of Electricity topic: using different modes of representations and analogies to teach Electricity*; *Importance of supporting Electricity topic knowledge building*; and *The role of practical work in the development of learners‛ scientific knowledge building*. While there were some differences in the teachers‛ approaches, they all dominated classroom talks which contradicted with their pedagogical link-making approaches and topic specific pedagogical content knowledge. Freire (1973) argued that teachers‛ dominant ―narration leads the students to memorize mechanically the narrated content. Worse yet, it turns them into _containers,‛ into _receptacles‛ to be _filled‛ by the teacher‖ (pp. 71-72).

All teachers adopted the narrator‛s role as they described and recounted demonstrations, calculations and classwork activities with prescriptive limited learners‛ involvement. Such an approach is detrimental to the learners‛ meaning–making process and deep understanding of knowledge, because learning involves participation in a socially dialogical environment (García-Carrión et al., 2020). Scott et al. (2011) asserted that dialogic approaches are the forms of discourses that motivate meaning-making for scientific conceptual development in the science classroom. Also, the socio-cultural theories of education place students‛ ideas at the centre of the learning process, thus learners should not be passive recipients of classroom discourse but encouraged to co-construct scientific knowledge with the teachers (Lehesvuori & Ametller, 2021). Thus, making links between learners‛ prior knowledge and scientific concepts to develop and maintain a scientific story in sub-theme two. For this development of scientific story, teachers worked with Big ideas of Electricity topic to link scientific concepts through different modes of representations and analogies, and this is discussed in the first sub-theme. Also, teachers' attempts to represent the Electricity topic knowledge macroscopically are also discussed as a third sub-theme including what teachers found difficult to teach through macroscopic representations (hands-on experiments or demonstrations). The following discussion details the first sub-theme.

9.2.1. The symbolic nature of Electricity: Using different modes of representations and analogies to teach Electricity topic

The teaching of Electricity topic requires teachers to communicate different concepts independently and relationally, communicate scientific practical work and calculation procedures and rules explicitly and connectedly, which is an expression of scientific knowledge at an intrapersonal (cognition) and interpersonal (communication) level (Vygotsky, 1987). According to Mudaly and Mpofu (2019) teachers are expected to show internal communication through what they say, write, draw or sketch, which means classroom and laboratory communications is generally seen in both effective and explicit talks and action.

All three teachers approached the representation of Electricity-related concepts differently during the lessons. However, they all used a combination of representations (REP) in a form of illustrations, demonstrations (models), mathematical equations, and diagrammatic representations and made links between modes of representations at macroscopic, sub-microscopic, and symbolic levels. It was important to use these representations to support conceptual understanding of electricity concepts, because learners should be able to describe what is seen at macroscopic level in terms of what is happening at the sub-microscopic and symbolic levels using diagrams and symbols (equations). Of importance, however, symbolic representations (equations) including electric circuit diagrams and electric circuit symbols dominated all the observed classroom teaching even though the pedagogical approaches by each teacher and outcomes of these representation-usages varied across teachers. Table 18 presents an overview of the lessons and episodes where teachers represented different worlds to develop learners' scientific knowledge building.

Table 18

Representation of the electricity concepts and content skills in each lesson

Levels of representations	Amanda	Sipho	Thando
Macroscopic representation *(Practical work)*	Lesson 1, Episode 2	None	Lesson 1, Episode 3
	Lesson 2, Episodes 1 & 3		Lesson 2, Episode 1
Sub-microscopic representations	Lesson 1, Episode 3	Lesson 1, Episodes 2 & 3	Lesson 1, Episodes 1,3 & 4
	Lesson 2, Episode 1 & 3	Lesson 2, Episodes 1 & 2	None
	None	None	Lesson 3, Episodes 2 & 3
			None
Symbolic representation *(diagrams, symbols-equations)*	Lesson 1, Episodes 3, 4 & 5	Lesson 1, Episodes 1, 2 & 3	None
	Lesson 2, Episodes 1 & 2	Lesson 2, Episodes 1 & 2	Lesson 2, Episodes 2, 3 & 4
	Lesson 3, Episodes 1,2 & 3	Lesson 3, Episode 1	Lesson 3, Episodes 1, 2 & 3
			Lesson 4, Episode 1

Amanda explicitly moved between macroscopic, sub-microscopic and symbolic representations in her lessons with an exception of her third lesson that only focused on mathematical equations (symbolic representations). Amanda‘s macroscopic representation within lessons may have helped learners be able to move between different scales of description and explanation as argued by Scott et al. (2011) while developing deep understanding of the Electricity concepts as argued by Ahmad et al. (2012). Moreover, it was only in the second lesson of Thando where she used macroscopic representations to demonstrate the components of an electric circuit. Even though she also linked her scientific explanations with real world phenomenon through demonstration in lesson 1, episode 3. Despite these two episodes, in the other lessons, Thando did not use macroscopic representations. While Amanda and Thando showed macroscopically and spoke about the components of an electric circuit, Sipho did not macroscopically show the components to his learners but only spoke about the components theoretically. Sipho‘s inability to represent the topic macroscopically may pose challenges for learners to develop deep understanding of the Electricity concepts as Scott et al. (2011) view this level of representation as the phenomena that bring science to life since it connects science to the environment and to society.

During the demonstrations, Amanda and Thando were still explaining the connection between concepts and the practical aspect while also promoting learners‘ deep understanding of the relationship between the scientific meanings of the concepts and the demonstrated phenomena. This practice was mostly common in Amanda‘s lessons as she allowed some learners to perform the practical work by themselves in order to demonstrate the electric circuit connection to their peers. This approach of learners‘ hands-on practical work is encouraged by science education researchers arguing that learners learn with understanding and they are able to achieve a deeper level of scientific understanding including scientific enquiry by finding things out for themselves (Said et al., 2014; Shana & Abulibdeh, 2020), which helps ignite their interest in physics (Needham, 2014). More importantly, this approach by Amanda provided a learning opportunity for learners to engage in a process of constructing knowledge by doing science (Shana & Abulibdeh, 2020). Despite her ideal approach to practical work especially when considering her teaching context of 85 learners in the classroom, when demonstrating the ammeter and voltmeter connections in a circuit in lesson 2, episode 3, Amanda made a connection mistake. Instead of using this situation as a teaching opportunity to say there was a mistake when connecting the voltmeter or ask learners where the mistake might have been, she was defensive and quickly passed over it.

Another interesting approach to represent different worlds to facilitate Electricity understanding by Thando (lesson 1, episode 3) and Amanda (lesson 1, episode 2) was their demonstration using the classroom electric switch wall. Both teachers were explaining the idea of opening and closing the switch. Thando called a learner to close and open the switch while the teacher explained the scientific process of electric current flow as the learner demonstrated. Unlike Amanda who personally demonstrated with the switch while explaining the electric current flow and learners were seated quietly observing the teacher performance. Of importance is that both teachers linked the real world phenomena (operation of a switch) with scientific explanation of the concept of current flow. This teaching approach is regarded by Scott et al. (2011) as beneficial as it enables learner‘s developing system of scientific concepts to become an edifice of scientific explanation and generalization with practical foundation.

Moreover, it was concerning that Sipho and Thando did not demonstrate simple and complex electric circuits especially when considering that simple electric circuits are in fact, from a learner‘s perspective, not simple as they involve physical processes such as the movement of electrons (Burde & Wilhelm, 2020). Also, Sipho and Thando‘s lack of electric circuit‘s demonstration undermines Mutende et al.‘s (2021) argument for demonstrations of complex abstract scientific concepts or process skills in order to promote deep learning. Therefore, Sipho and Thando denied learners an opportunity to have their critical thinking skills, problem solving and creativity stimulated through practical work including demonstrations of electric circuits.

Instead of macroscopic representations, Sipho drew and used electric circuit diagrams to explain concepts as evident in his episodes in Table 18. Even though these diagrams could only represent Electricity concepts at sub-microscopic level as they are conceptualized as abstract models. Scott et al. (2011) advised against such practices when arguing for teachers not to leave concepts at the abstract level but to move between different levels of representations for the development of deep understanding of scientific knowledge. Interestingly, Amanda and Thando also drew and used electric circuit diagrams including electric circuit components. However, these two teachers were moving between macroscopic and sub-microscopic representations. To exemplify this, consider Amanda‘s lesson 1, episode 2 where she explained and described in terms of macroscopic representation the operations of a classroom switch in relation to the sub-microscopic behaviour of electric current in a complete circuit. Moreover, Thando also starts her lesson 1, episodes 1 to 3 with sub-microscopic representations which are then linked with the macroscopic representation in lesson 2, episode 1. After which, both the sub-microscopic and macroscopic levels of representations are applied symbolically in lesson 2, episode 2.

Moreover, Burde and Wilhelm (2020) proposed that teaching at the secondary school level should focus more on a conceptual understanding of circuits and less on a quantitative circuit analysis. From this study, Amanda and Thando have heeded to this proposal. However, Sipho focused more on the quantitative circuit analysis as evident from the majority of episodes in his lessons. Interestingly, Amanda and Thando demonstrated the components of an electric circuit. Mutende et al. (2021) argue that interactive teaching methods such as demonstrations helps facilitate the construction of scientific knowledge and enhances learners‘ potential for development of critical thinking and problem solving skills. Therefore, it can be argued that Amanda and Thando‘s demonstrative approaches helped learners construct scientific meanings of electric circuits and their components.

Furthermore, it was concerning to observe that teachers used an average of 24 to 45 levels of representations in their overall lessons (see Appendix 12) but only used an average of 1 to 8 links between different scales and levels of explanations (see Appendix 12). The implications are that, learners were not afforded an opportunity to link the different modes of representations to see how they come together to paint a full picture of concepts and processes for deep understanding of Electricity topic (Mavhunga, 2012; Scott et al., 2011). However, when moving between different modes of representations, analogies were also used by Sipho and Thando. In his first lesson, episode 2 when teaching about connection of a voltmeter in a circuit, Sipho used an analogy where he likened the relationship between charge flow and amount of resistance to having two big desks in the classroom and him not being able to pass through the desks.

Of concern, however it was the lack of differentiation in principles between the analogy and the target scientific idea as the teacher also mentioned that he could not pass through the desks implying that current is completely blocked by the resistance which may not be scientifically true. This point to the importance of highlighting limitations of analogies to limit scientific misconceptions being caused by the used analogy as argued by Webb (1985) that some analogies can produce misconceptions. Thando also used an analogy in her first lesson, episode 4 where she related emf and internal resistance to a pipe of water. Thando gave her analogy in learner‘s home language (IsiZulu) and then linked it to the science target concept through LOLT (English). Like Sipho, limitations of the analogy were not highlighted in Thando‘s episode. Though two different analogies used by Sipho and Thando but both lacked the link to differentiate and integrate from the target science concepts and process.

Additionally, from the observation of how learners engaged with Thando‘s analogy, the analogy was beneficial in assisting learners to understand the target scientific concepts as argued by Galtire (2019) when known and relevant analogies are used. The use of relevant and adequate analogies during teaching of Electricity also helps to build science knowledge from what learners already know. The use of analogies is beneficial for teaching science but when used, careful thought must be applied in selecting and teaching with analogies. One of the cautions to be considered by teachers is making known the short comings of an analogy as it may propagate the development of alternative concepts (Dagher, 1995). As argued further by Dagher (1995) analogies may bring conceptualisation of knowledge in learners but, if not well chosen and when its short comings are not explained to learners, it may mislead learners. In light of this view of Dagher, some rural physical science teachers did not make clear the intentions of their chosen analogies and the individual concepts demonstrated through the used analogies were not explicitly explained in teaching about Electricity. In the following sub-theme, I focus on teachers' practices to support Electricity topic knowledge building.

9.2.2. Importance of supporting Electricity topic knowledge building

Teachers made various pedagogical links of their knowledge of the Electricity topic. Pedagogical link-making between scientific concepts and their sequencing to develop a scientific story featured mostly in teachers' attempts to support Electricity topic knowledge building. It was important for teachers to focus on curricular saliency including scaffolding of concepts and concept progression and teacher emphasis on what is regarded as important concepts to support Electricity knowledge building. Knowledge Building is premised on the idea that each learner is a legitimate contributor in the science knowledge building process, thus learners need to work creatively with ideas and to see themselves as active contributors in science classrooms (Soliman et al., 2021). Therefore, teachers should support knowledge building by considering what is difficult to teach or learn about concepts in a topic while also working with learner prior knowledge towards target scientific understanding because new knowledge builds on prior knowledge. This is important because knowledge is not effectively built if scientific knowledge remains at the level of theoretical ideas divorced from learners' lived realities and contexts (Rusznyak et al., 2021), hence the importance of teachers' link-making between everyday and scientific ways of explaining; and links between scientific explanations and real world phenomena. Also, as discussed in the previous sub-theme, multiple modes of representations including the use of analogies helped teachers in this study to support learners in developing Electricity topic knowledge.

Amanda and Thando introduced their lessons more often by asking questions that relates to Grade 9 work or previous lessons of Grade 10 syllabus on Electricity topic especially electric circuits with the aim to confirm, infer, and rarely to determine learners' level of understanding of the topic. Consider for example, Amanda's lesson 1, episode 1 which is characterised by meso and macro time scale for continuity link-making and Thando's lesson 1, episode 2 which is characterised by micro and macro time scale for link-making to promote continuity. However, this was limited to Sipho's lessons. An interesting divergence between Amanda (lesson 1, episode 1) and Thando's (lesson 1, episode 2) use of LPK was observed in these episodes where Amanda drew from LPK by involving learners while Thando referred to LPK without learner interaction. Amanda‘s practice is encouraged by Diaz (2017) who argues for establishment of LPK and if found active, sufficient, appropriate and accurate, it could help in learning since learners actively construct their understanding by trying to connect new information with their prior knowledge. With the established scientifically sound learner prior knowledge, learners are more likely to build on this knowledge constructively and of concern this practice was limited in all teachers lessons.

To exemplify teachers‘ practices on working with learner prior knowledge, all three teachers integrated explicitly and implicitly the pedagogical link to promote continuity by drawing or referring to learner prior knowledge, though Sipho limitedly did this. When drawing from LPK, some teachers confronted learners‘ misconceptions, for example in lesson 1, episode 3, Thando said, ―So Sizwe can you please close the switch for us? He has closed the switch that is why we have got Electricity…Whenever you close the switch you get light so whenever you open the switch, the light goes off‖. Thando made links to differentiate between everyday and scientific ways of explaining by linking the scientific explanations and real world phenomena through the use of macroscopic level of representation. The complex and interconnected link-making by Thando could lead to effective learning because the extent of understanding depends upon the number and quality of the links made (Scott et al., 2011). Notwithstanding the quality of links made by teachers, the dominant teachers‘ practice related to teachers constant reference to pre-requisite knowledge. For example, when introducing electric circuits, Sipho stated, ―a simple electric circuit, we said it must consist of any power source… So this is a power source… Previously we talked of the electrostatics; we said we look at the charges that are at rest‖. Sipho had demonstrated a level of awareness for learners‘ pre-requisite knowledge as suggested by Aydin and Boz (2013) but failed to get learners‘ insights into what they know, to what they do not know, and the kinds of alternative conceptions held by learners (Urban-Woldron, 2014).

Furthermore, Amanda and Thando particularly marked key ideas when working on developing the scientific story through repeating an idea after learners. Tamunda (2018) acknowledged this pedagogical approach to teaching Electricity as useful but also mentioned the problems associated with it, for example wastage of valuable time if incorrectly used as was observed mostly in this study. This means the approach has to be carefully used and teachers in this study did not use it productively and they could improve on this practice. Furthermore, Thando‘s lessons were characterized by ―remember, I said to you…‖ which does not seek to solicit learner understanding but teacher‘s self-confirmation of the supposed covered content knowledge. While this is the case, Amanda‘s lessons were characterized by the combination of drawing from learner prior knowledge and referring to pre-requisite knowledge from previous grades, lessons, and more often from within the taught lesson. Of concern, was Amanda‘s poor pedagogical considerations and integration of learner‘s prior knowledge in the lessons of Sipho. This suggests that Sipho developed scientific ideas without learners‘ considerations even though Scott et al. (2011) argue that a teacher must take some responsibility for actually pointing to the connections that need to be made and in helping their learners work through these knowledge connections.

Moreover, though learner prior knowledge is referred to by teachers, learners‘ inputs that draws from their prior knowledge was not encouraged in most of the lessons. Therefore, in the observed lessons, there was little or no chance for learners to express what they would have been taught in previous sections or previous lessons except in some parts of Amanda‘s lessons. With the different approaches by teachers, teachers generally missed on the opportunity to understand learner misconceptions on previous lessons or grades and or current or upcoming concepts. Even though, Qian et al. (2020) argue for the importance of understanding learners‘ misconceptions when teaching. This is important because misconceptions hamper learners' deep understanding of scientific explanations (Chen et al., 2020), so teachers should address and utilize learners‘ misconceptions to enhance scientific conceptual understanding (Moodley & Gaigher, 2019), which was not observed in this study.

Lastly, teachers drew from LPK to connect scientific concepts from within and across lessons to show how the concepts fit together in an interlinking system to form the Bid ideas of Electricity topic. These content links helped teachers to develop and support Electricity topic knowledge building because the usefulness of concepts comes from their connections to one another (Lemke, 1990). Of concern however, it was the teachers who made links for learners. The concepts of the Electricity topic were integrated and differentiated during the lessons. Amanda and Sipho integrated concepts more in their lessons while Thando differentiated concepts more in her lessons as evident in Appendix 12. Consider the example from Thando‘s lesson 1, episode 3 where the teacher makes content links to integrate the concepts of current and potential difference while also differentiating between potential difference and emf through the application of the concept of current. Amanda,

―So, if there is a flow of current, like diagram A, we talk of potential difference. So now we are talking about potential difference. Here we got a circuit but now we find that the charges are not moving so there is no flow of current…So now we are talking about emf…So in other words, when we look at the emf, we are talking about maximum voltage that a battery can deliver…but if you take that battery and then now you connect it completely in such a way that the charges will move…we will find that we are talking about potential difference…so that‘s the difference between emf and potential difference.‖

The teacher further makes a link to integrate the concepts through the equation, V=W/Q in the subsequent episode 4 which was then linked to I=Q/t in lesson 2, episode 1. A similar scientific concepts links was made by Sipho in lesson 1, episode 1. However, Sipho did only linked potential difference and current without consideration of emf. Interestingly, Sipho immediately linked the concepts with I=Q/t and Ohm‘s Law (R=VI). Interestingly, in lesson 1, episode 1, Thando linked current to charge flow and made a link to differentiate between current and conventional current by drawing from the nature of science, and all this was further linked to electrons. Thando‘s complex link-making were done through the diagrammatic representation in Photograph 62. Though explaining similar concepts (processes), teachers approached it differently but they presented it explicitly so that learners could appreciate the relationships between the listed scientific concepts for deeper understanding (Scott et al., 2011). In the following sub-theme, I focus on teachers‘ intended and observable practical work practices (macroscopic representations) and its role in developing learners‘ scientific knowledge building.

9.2.1. The role of practical work in the development of learners' scientific knowledge building

The nature of science combines theory where content is taught and the practical work for learners to see theories and concepts in action. The Chinese Proverb, ‗*Tell me, I‘ll forget. Show me, I‘ll remember…Involve me and I will understand*‘ was mentioned by Thando, and it centralises practical work to support scientific conceptual understanding for Electricity topic. Notwithstanding the importance of practical work in teaching and learning scientific ideas (Millar, 2004; Heeralal, 2014), the rural schools are characterized by limited (or lack of) science laboratories, instruments and chemicals for practical work to be conducted (Heeralal, 2014; Mtsi & Maphosa, 2016). Therefore, only two teachers, Amanda and Thando did practical work during the lessons, in the form of demonstrations, to demonstrate the different components of electric circuits and how to connect them using the theoretical language to show the relationship with the practical aspect. While Amanda used practical work in the classroom in lesson 1 and in the laboratory in lesson 2 and gave learners the opportunity to do the practical work during lesson 2, Thando only showed learners the different components of the electric circuits in class and did not demonstrate how to connect them in the electric circuit, nor give learners an opportunity to practice how to connect the components into an electric circuit. Thus, Thando‘s learners did not do the demonstration to understand how to connect the different components in relation to the theoretical content, even though this link between practical and theoretical knowledge in Electricity topic is crucial for examination purposes. Also, practical work has to engage learners in thinking processes for purposes of conceptual understanding (Jokiranta, 2014; Mudau & Tabane, 2014), not for learners to only visualise components of electric circuits without deep scientific understanding of the components in a real-life electric circuit as was observed in Thando‘s lessons.

Moreover, learners were limitedly involved only in Amanda‘s lessons despite learners‘ hands-on practical work is encouraged by science education researchers for learners to find things out for themselves, at the same time learn with understanding and achieve deeper scientific knowledge (Said et al., 2014; Shana & Abulibdeh, 2020), which helps ignite their interest in physics (Needham, 2014). Without overlooking the challenges with laboratories in rural schools, Amanda‘s advantage of taking learners to the laboratory was to allow them to do practical work, and develop laboratory skills and demonstrate their understanding of the procedures with correct use and explanation of different concepts. Shana and Abulibdeh (2020) posit that practical work has been shown to help improve students‘ communication skills, in order to solve problems in science and thus become more motivated in science.

Unfortunately, in Amanda‘s lesson 2, episode 3 learners did not articulate what they were doing during the demonstration, as the teacher said ―We want to see whether they (learners) have seen what I was doing, just the demonstration‖, which happened at micro-short time scale to develop the scientific story (Scott et al., 2011; Lehesvuori & Ametller, 2021). Even though a group of learners did the hands-on practical work, because the teacher did all the explanation of the learners‘ procedures, there was no difference between observation and presentation of data for the learners while they were sitting down. It was unsurprising that learners confirmed lack of understanding the procedure when the teacher asked them, “You have seen what is happening?" and learners said "No", because Amanda only worked with the learners on the front bench in the laboratory and did not include learners who were sitting down in the laboratory. Although science education researchers (Tobin, 1990; Kay, 2014; Okam & Zakari, 2017; Shana & Abulibdeh, 2020) note that laboratory activities allow learners to learn with understanding, at the same time, engage in a process of constructing knowledge by doing science, it was not the case for all the learners in this study, including Amanda‘s learners, who went to the laboratory.

The reason Amanda‘s learners were in the same position as Thando and Sipho‘s learners who did not do any hands-on practical work, because it cannot be confirmed that they learnt and understood the relationship between theory and practice and developed their scientific knowledge. For example, while guided by the teacher, learners misused the scientific tools that resulted to the voltmeter overshooting after connection, and there was a burning smell coming from the ammeter because the connecting wires were overheating, which represented learners‘ misunderstanding of the practical work procedure and scientific knowledge gap. Amanda did not use the demonstration challenges as an opportunity and address learners‘ mistakes and effectively explain the reasons for the ‗failure‘, to support learners‘ science knowledge building. This addresses some researchers concerns about laboratory practical work (Hodson, 1991; Kay, 2014; Sotiriou et al., 2017), who argue that practical work in many schools is ill-conceived, confused and unproductive because what goes on in the laboratory contributes little to the students‘ learning of science, as they usually follow instructions in the lab manual step by step and does not give students the chance for creativity and cannot connect the work to real life. While this might be the case, theoretical delivery and practical work in science are still intertwined and cannot be separated, because both levels of understanding are examined in South Africa to assess learners‘ knowledge.

The Department of Basic Education (DBE) acknowledges that Electricity topic is failed ―…due to a lack of emphasis on practical work…‖ which was observed in Thando and Sipho‘s classrooms, and was ineffective in Amanda‘s lessons. While the lack of hands-on practical work and demonstration of the electric circuit components in Sipho‘s lessons linked with his examination-centred pedagogical approach, as he used the examination guide to teach the exact content to prepare learners for the examination theory, Thando and Amanda‘s lessons were eclectic with the dominance of interactive / evaluative / authoritative (IEA) communicative approach. Thus, Amanda and Thando dominantly used the IEA, even though differently because of the dominant tsPCK, especially CSA, WDT/L, and CTS. The IEA approach was not identified in Scott et al., (2011) research, which is the contribution from this study and represents teachers' complex approaches within this rural context.

Moreover, Sipho reflected on the teaching and learning of Electricity topic and the importance of practical work, even though he did not use practical work,

> We theorize it (Electricity topic teaching), learning is a matter of absorbing whilst we need to be more practical and put more effort. We work harder in a way that learners should be able to understand and answer questions whilst it needs us to be more practical in order to understand it. That is where they lose understanding as it's more practical than when we used to learn it.

Sipho acknowledges his ‗theoretical' approach to teaching Electricity which resulted to the learners passively 'absorbing' the content as proof for learning. According to Sipho, absorption of content is necessary for learners to answer assessment questions, which encourages surface learning for memorisation of information to be regurgitated during assessments.

It was interesting that Sipho realised the importance of practical work for the understanding of Electricity topic even though he did not use it in his observed lessons. However, Sipho claimed to have an alternative to hands-on practical work, ―we have a way of doing it through demonstrations most of the time but on its own its (Electricity) practical‖ bringing forth the level of demonstration for learners to observe, as noted by Millar (2004) that practical work should involve at some point the learner in observing or manipulating real objects and materials. From the observed lessons however, Sipho did not use any demonstrations but facilitated learning though examination guideline. Sipho's approach influenced learners' approach to the learning of the topic, as they were passively listening to the teacher, including during the engagement with the activities. This approach did not guarantee that learners developed deep understanding of scientific knowledge for their own explanations and life-long learning as they were not given opportunities during the lessons to reflect on and co-construct scientific knowledge and meanings.

In the absence of any form of practical work, Sipho argued that he only introduces learners into the scientific discourse through painting a picture of what is to be learnt, which does not promote deep understanding of scientific concepts and skills. Sipho explained,

> So basically that‘s how we teach, we follow the exam guideline, and then we paint a picture to enable understanding. But then, we do have apparatus even though some are not working but we are able to show them that this is an ammeter, this is a voltmeter and when you connect, you connect like this.

The above utterances of painting a picture, suggests that the teacher did not teach the concepts for deep understanding. Sipho further claimed that he was able to show components of a circuit and their connection, however from the observed lessons he did not do any demonstrations. This demonstrates the importance of classroom observations used with VRSI for triangulation purposes to compare the pedagogical approaches advocated through VSRI and those used during the lessons.

Unlike Sipho‘s classroom practice, Thando used some demonstrations for the components of the circuit to learners, even though she did not include learners to engage with components in circuit‘s connections. To talk about her pedagogical practices concerning practical work, Thando articulated,

> I try by all means to make sure that whatever that I talk about, I show them. It doesn‘t matter how tiny that particular thing is to me or when I look at it but I know that when a child looks at it, it has a difference then when I do it orally or as a theory only.

Thando claimed to have shown learners whatever she was talking about during the lessons, which was not the case from the observed lessons as she only showed components of electric circuit in lesson 2. The phrase ‗whatever I talk about, I show them‘ positions the teacher as the main character in classroom talk and emphasises on who does the work in class for the learners hence teaching for teacher‘s own learning (second theme). Through demonstrations it is expected that learners would observe the demonstrated phenomenon which is regarded as a first form of learner participation in a culture of practice as learners observe from the boundary (Lave & Wenger, 1991). As mentioned earlier, the ‗showing‘ by Thando was guided by her teaching philosophy underpinned in the Chinese Proverb, ―tell me, I‘ll forget. Show me, I‘ll remember… Involve me and I will understand‖ (Thando). The underlying assumption of showing learners rather than involving them is that they will remember what they have been shown, possibly during assessments procedures, which did not guarantee understanding of the scientific knowledge during the lesson.

While noting the importance of practical work, Amanda explained why not everything spoken about in class is demonstrable. Amanda said, "Let‘s start from Grade 10, they are in a big number so we arrange them in groups because it is very important that they have to do practicals as it‘s very important.” However, overcrowded classroom space for Amanda was the challenge for effective practical work, even though she would have preferred to arrange learners in groups for experiential learning, this was not observed during her teaching. Instead, whole class demonstrations were observed and laboratory hands-on practical work that involved a group of 4 learners. The 4 learners comprised of two girls and two boys who conducted the hands-on practical work and demonstrated the circuit connections to the whole class. Amanda helped the learners by doing all the talking and learners dominantly confirmed and completed the teacher‘s sentences. Taking over the explanation responsibility from learners was confirmed by the following phrase, “For Electricity, classroom discussion is not that much‖ which meant the dominance of teacher talk during teaching while learners were to follow and confirm closed evaluative questions and feedback as was observed in Amanda and Thando‘s lessons.

The importance of practical work for Electricity teaching for Amanda, involved learners being able to “…engage themselves in handling the apparatus and they must be able to connect, I have to observe them connecting so that‘s why I would arrange them in groups so that each and every one can be involved”. Unlike Thando who has the same number of learners as Amanda in Grade 10 science class, Amanda suggested to move beyond teacher-talk to demonstrations and further to involving learners for understanding, which was observed during the lessons. Even though Amanda recognised the importance of involving individual learners for their internalised practical skills of handling apparatus, connecting electric circuits, and conceptual understanding, she did not involve even half of the learners as idealized in the above excerpt. While the difficulty to include all learners during practical work was understandable for 85 learners, Amanda could have planned the activity because she knew the resource limitations and number of learners she had, which addresses the importance of careful lesson planning.

Furthermore, there were contradictions between Amanda‘s pedagogical approach and perceptions, as noted below when she talked about practical work making the lesson interesting,

> Yes, practical make them eager to learn physical science. They would say “Ma‘am when are you coming to teach us?” because they love it when they engage themselves

> rather than talking too much you see…If they do practicals, that is where they are most interested in this topic

Amanda refers to practical work as a tool to engage learners and ultimately an instrument to stimulate learner interest in the subject, even though it was limitedly used in her lessons. According to Amanda, practical work act as an anchor in her teaching which helps present scientific knowledge and skills within authentic contexts and eventually generate learner interest in the scientific content as also argued by Zydney and Hasselbring (2014). This could explain Amanda‘s attempt to conduct practical work in her lesson 2. The observed minimal practical work in Amanda, Thando and Sipho‘s teaching approaches questions the extent to which learners‘ interests is stimulated in their teaching practice and ultimately learners‘ knowledge building of scientific content including scientific practical knowledge.

Given the discussed importance of practical work in science classrooms, its absence in learning for conceptual understanding becomes difficult. To talk about the implications of not doing practical work, Sipho stated,

> …they are based on them not having a clue, or don‘t have a picture of what we‘re talking about. You will find that sometimes we talk about something and that‘s just it, without any further understanding. The most challenging part that makes this topic to be difficult is that they don‘t have a practical picture of what is spoken about. They don‘t pass this topic, particularly when they are in Grade 12 because we continue with it if from previous grades and it‘s exactly the same.

Sipho‘s response demonstrated difficulties in understanding concepts of Electricity topic in the absence of practical work approach. Part of the challenges faced by learners, Sipho contended, is the lack of correct mental pictures of scientific concepts which should be created using practical work. This is partly because content knowledge is only verbally spoken about with little or no tools to aid teaching and learning of the discussed concepts and skills. As a result, Sipho maintained that learners perform poorly in electricity related-concepts due to lack of practical pictures of taught content. The lack of practical pictures, which according to Sipho should be provided by practical work, deprived learners of the opportunity to get and work with the basic foundations of Electricity topic in Grade 10.

As a result of being denied the opportunity to create mental pictures which is enabled by practical work, "only a few [learners] can be able to do it [Electricity] practically, but the theory part, they are able to understand… it would be more effective if there was a practical for them to see and experience what is happening”. Sipho‘s comment suggests that his learners understands the content and skills but cannot understand it in-context and apply practically. If that is the case, his learners could be argued that they have memorised the taught content and skills but lacks conceptual understanding and its practical application in solving problems. Nevertheless, Sipho affirmed the importance of practical work where learners do not only ‘see‘ (shown) what is happening but can also experience it (get engaged or involved). Practical work was valued by all three teachers even though only practised by Amanda and Thando. When used, practical work was limitedly used with the aim of demonstrating concepts and scientific processes to learners rather than engaging learners for meaningful experiential learning. Part of the limitations included the authoritative communicative approach by all teachers which limited learners‘ engagements.

This sub-theme has exposed teachers‘ pedagogical approaches for the Electricity topic. Knowledge of teaching approaches covers knowledge of both subject-specific and topic specific teaching strategies. The teacher should be able to use appropriate activities in teaching, use real life examples and analogies in teaching and make use of different representations to best represent the concepts of the topic of Electricity. Mavhunga and Rollnick (2013) in their study found that there is a reciprocal relationship, between PCK and pedagogical transformations evident in the significant improvement in the understanding of content knowledge in the topic. The findings of this study are consistent to that of Mavhunga and Rollnick (2013) because teachers in this study were able to use a variety of teaching approaches to represent content knowledge in their classrooms. Teachers used available teaching materials to teach the topic of Electricity and maximised on contextual knowledge which served as LPK especially when giving examples and when explaining through analogies. Bizimana and Orodho (2014) revealed that the challenges of availability and adequacy of learning resources was found to negatively affect teacher effectiveness in the use of teaching methods as well as focus on individual learner as was observed in this study also.

The discussed teacher‘s approaches highlights physical science teachers overuse of traditional teaching approaches such as dominance of teacher talk (chalk and talk), textbook reading, low-level series of questions during teaching, and show and tell among others. The physical science teachers‘ views were that the lack of resources does not allow them to integrate a variety of teaching and learning strategies. As a result, Electricity teaching and learning is mostly informed by the teacher-centered approach, exam oriented approach and content-driven approaches. All three schools had science laboratories though old, dysfunctional and used as classrooms for teaching especially physical science teaching. The following section details teachers‘ communicative approaches and patterns of discourse in relation to dominant pedagogical approaches for Electricity topic.

9.3. Teaching Electricity topic and concepts for teachers’ own learning

All teachers dominated the lessons because learners‘ participation was limited to completing teachers‘ sentences and closed evaluative and feedback questions that needed one confirmative answers. Dahal et al. (2019) extrapolate that ―Questioning has been used to provide a variety of situations that increase student involvement, regulate classroom processes, focus attention on a particular issue or concept, structure a task in order to maximize learning and understanding, assess students‘ prior and current knowledge‖ (p. 122). Considering the role and importance of questioning during the lessons, teachers used questions to constrain learners‘ deep learning and understanding of Electricity topic and related concepts (Ahmad et al., 2012). Even when teachers recapped information, they overlooked drawing from the learners‘ prior knowledge (LPK) to determine whether and how much learners understood about the topic and the relationships between concepts that develop scientific story (LMSS) and promote continuity (LMPC). Thus, teachers treated the teaching of Electricity topic about giving learners scientific facts, because teachers asked and answered their own questions, initiated – responded - confirmed (IRC) their information without giving learners opportunities to show-case their acquired and internalised scientific knowledge. There were restricted opportunities to answer teachers‘ questions as evidence of their understanding or lack thereof, for teachers‘ awareness of learners‘ challenged sections and misconceptions. Freire (1973, p. 80) argued that in this transmission style, “the students are not called to know, but to memorise the contents narrated by the teacher”, and promote regurgitation of information during assessments.

There were two sub-themes that emerged from this theme, which are: closed evaluative and feedback authoritative communicative approaches; initiation – response - confirmatory (IRC) approach. These approaches resulted to teachers overlooking the importance of encouraging learners‘ participation in the teaching and learning process, to support the electricity knowledge building and internalisation of the topic and related concepts for life-long learning and understanding. From the classrooms and laboratory observations, teachers appeared to have mistrusted learners, even after they have already taught some concepts, and resulted to them teaching for their own learning as learners were overlooked in the process.

9.3.1. Closed evaluative and feedback authoritative communicative approaches

Teacher talk is essential for teaching and learning process, and effective communication of science education topics and related concepts during teaching depends on teacher‘s content knowledge. Classroom talk can be expository, interrogatory, exploratory, dialogic or evaluative (Alexander, 2001). This means, classroom talk may transmit information or explain ideas; it may entail the asking and answering of different questions; it may offer opportunities for open-ended discussion; it may build up shared understanding through structured, challenging yet reciprocated talk; or it may weigh up and judge what has been said and done. Some of these complex communications were observed in the teachers‘ classrooms for this study, especially the dominant authoritative transmission and explanation of electricity content and concepts, and teachers‘ closed ended questions and answers and the learners‘ closed ended answers approach. Expectedly, all three teachers took ownership of the electricity topic content to build knowledge of the topic through different ways of explanations that included everyday, scientific, and real world using code-mixing where necessary. The concerns with the teachers‘ traditional factual knowledge ‘deposit‘ (Sirotová, 2016) and closed ended questions, was the limitation of learners‘ cognitive engagement and the promotion of passive learning during the lessons and demonstrations. Even when Amanda allowed learners to do practical work in the laboratory, she continued to ask evaluative closed questions and limited feedback responses for the learners, and they became voiceless demonstrators in the front bench.

Again, all three teachers used closed evaluative questions and closed feedback, for example, Thando‘s lesson:

> ―the difference between these two is that an ammeter measures the current and it is connected in? [**Learners**: series]; This one is measuring the what? The voltage, and it is connected in? [**Learners**: parallel]‖. During Amanda‘s lessons about formulae and calculations: ―Now using the formula V=W/Q, our work done is? [**Learners:** 10] Its 10 and then our charge [**Learners:** Five] is five. When you divide, you get 2, so this is the answer. How do we calculate the charge, we say 4200 divided by 220, it will be… [**Learners:** 19 Coulombs]‖.

Considering this approach, it is difficult to say that learners‘ Electricity topic knowledge was deeply developed and will be able to be described connectedly and coherently, what is seen at macroscopic level in terms of what is happening at the microscopic and symbolic levels using diagrams and drawings.

The dominant use of link - making between scientific explanations and real world phenomena through code – mixing, and making links between everyday and scientific ways of explaining through differentiation represented teachers‘ communications during the electricity lessons. Thus, teacher‘s communication during the lessons exemplified various issues, such as, the understanding of the curriculum standards or lack thereof (CSA), teaching for compliance and examination particularly Sipho for the latter but eventually all teachers were complying with curricular standards, nature of lesson planning (though this study did not focus on this), and limited content knowledge and/or pedagogical content knowledge especially Sipho even though Thando also to a certain extent and Amanda especially with the demonstrations. Sipho constantly referred to the examination guide during teaching and commented during VSRI that examination guide has all the definitions and content, "Which means everything that is going to be asked during the exam is here. Even what you must teach, you can but you should not move away from the exam guideline". Amanda also concurred with this view and argued that "When doing this I use exam guidelines, no definition from the textbook. If you write McMillan (textbook publisher) it‘s your own problem but during marking they mark the CAPS document or the exam guidelines only definitions". The examination driven approach seems to have boxed teachers and their knowledge and limited it to exam guide rather than conceptual understanding.

Even though closed evaluative and feedback authoritative communicative approaches have their disadvantages in teaching but it worked for teachers in presenting and covering content knowledge (CSA) especially when considering the dominance of teachers links between scientific concepts in each observed lesson (see Appendix 12). Notwithstanding the approaches‘ usefulness in covering content knowledge but it denied learners participation opportunities and thus its impact on learning cannot be confirmed. Therefore, from how teachers transformed content knowledge for the learners, it is not clear whether this approach made it easy for learners to understand the electricity content. Especially that some teachers struggled to effectively communicate and explain switching on and off concept. Also, when considering that most of Sipho‘s learners and Amanda‘s to some extent generally gave wrong answers when asked questions including when given an opportunity for Amanda‘s learners to write their problem-solving responses on the chalkboard, meaningful learning of content knowledge does not seem to have happened through the use of closed evaluative and feedback authoritative communicative approaches.

It follows then that teachers draw on different forms of tsPCK to teach topics in their subjects. However, it is important that teachers are always conscious that the process of content knowledge transformation is not restricted to own evaluative and feedback session but should open the lesson to learners also. This means, learners‘ prior knowledge should be drawn upon when teaching a topic, including considerations of what learners may find difficult to learn. These are important aspects of learning to be addressed by teachers during teaching, and unfortunately the closed evaluative and feedback authoritative communicative approaches employed by teachers did not promote effective use of LPK and considerations of WDT/L. Teachers‘ communicative approaches led to distinctive interaction patterns initiated by teachers and these patterns are discussed in the following sub-theme.

9.3.2. Initiation – Response - Confirmatory (IRC) approach

Alexander (2018) argues for a dialogic teaching, where teachers are to help learners grasp that learning is an interactive process and that understanding builds through joint activity between teacher and learner and among learners in collaboration. To promote a dialogic teaching, teachers in this study used superficial interactive teaching approaches where teachers led learners through a sequence of instructional questions which were mostly answered by teachers and where learners were involved, they were required to mostly provide confirmatory answers to teacher‘s instructional questions. Also, all teachers used a lecture method where the focus of teaching was on the representation of facts and important information from the content (Mortimer & Scott, 2003). The lecturing method resulted to teachers‘ dominance of authoritarian communicative approaches since teachers limitedly allowed learners to respond to questions or raise any question, instead teachers would answer their own questions. The dominance of teacher talk and actions in solving problem-based calculations relates to what Paulo Freire refers to as the banking method of teaching through which knowledge is deposited or transmitted to learners as though they are empty vessels and their duty is to take notes while the teacher does the talking (Freire, 2018). The assumption in this method is that teachers teach while learners learn. This has a link to Fox‘s (1983) personal theories of teaching, particularly transfer theory which treats learners as passive recipients of knowledge while the teacher is the reservoir of knowledge.

The teacher‛s practices shaped classroom interactions where classroom discourse was centred on the teacher. Establishing patterns of discourse helps the teacher to be able to explore learners‛ ideas during teaching (Mortimer & Scott, 2003) and for the teacher to carefully plan their appropriate interventions for the development of deep scientific understanding. When the pattern has been well thought of, the teacher could encourage learners to share their ideas, evaluate and respond to learners and thereby allowing learners to sustain the interaction for effective meaning-making. However, the nature of observed teachers‛ patterns of discourse promoted teacher‛s authoritative communicative approach instead of supporting dialogic interactions. Mortimer and Scott (2003) and Rustandi and Mubarok (2017) argue that in the triadic I-R-E/F interaction pattern, the R represents the learner Response. Contrary to literature in this study, Response in the pattern of discourse was dominantly by teachers. This is because teachers limitedly gave waiting for learners to respond because teachers argued that learners do not participate or respond to teaching questions. Therefore, instead of teacher-learner-teacher interaction, teacher-teacher patterns were observed in this study. For example,

> **Amanda:** When you look at electric circuit, what is the role of electric circuit? It allows charges to move through. If I can connect all these components here and then what will happen? The charges will move and know that those charges that are moving, these are the positive charge as well as negative charge. And then how is this flow of charges? We said it moves from positive to a negative terminal of a battery. This is a positive terminal of a battery and a negative terminal of a battery.

During the introduction of current electricity in Thando‛s lesson:

> **Thando**: What is current? Current, it is the rate at which charge flows. Whenever we talk about the direction of the current your arrow must move from where it‛s positive and move towards the what? If it‛s said that it is a full circuit it means that your current moves in an anti-clockwise direction and so the fact that it was agreed on by the whole world, gives it the named conventional current. What do we mean by conventional current? We mean that the current always flows from positive to negative…now the big question is, then what flows from the negative to the positive

because there is something flowing from here to there you see because this one is negative, right? So it means on the negative side what is excess?

The teachers initiated the self-exchange by posing a series of questions to which both teachers respond to their own questions. The practice of confirming teacher‘s own responses through follow-up questions and elaborations is also observed in the above teacher patterns. In these scenarios, learners are denied an opportunity to participate in the lesson thus being passive passengers while the teacher teaches and learns for him/herself. This practice undermines learners‘ prior knowledge (LPK) of the topic taught. The implications are that learners are not supported in developing their own point of view (Mortimer & Scott, 2003). Also, learners‘ alternative points of views are not given a space in the teaching process and in turn teachers could not effectively explore learners‘ ideas.

9.4. Factors that shape rural teachers' pedagogical approaches

Previous research, such as Emerging voices (2005), says that schools in rural areas function under unpleasant conditions. This study revealed that this is still the case although it has been twenty-five years of a democratic South Africa, and this influences the experiences of teaching and learning. The teacher‘s approaches were limited by the inadequacy of Teaching and Learning Support Material (TLSM), particularly Electricity topic kits for practical work for all learners. These materials are important to visualise concepts of a topic. According to Larson and Street (2011), TLSM are a necessary key feature of effective teaching and learning. This is also emphasised by Beeland (2002) and Mayer and Massa (2003) who assert that visuals make teaching and learning result in better understanding of the content.

Regrettably, majority of Grade 10 rural physical science learners in Vryheid schools required learners to rely on their own imagination and the imagery that the teacher and textbooks make during their engagement with the physical science content for example current flow, voltage dividers and current dividers, etc. This is contrary to Laurillad (2002) who asserts that teaching is a process of transferring knowledge through showing, telling and demonstration. For the physical science teachers in this study, the teaching process covered mostly the telling and, to a limited extent, the showing part. Teacher‘s contextualisation of circuits, current and resistance is through their rural lenses where used analogies are made using the immediate learners‘ context, practical work is limited to demonstrations to due overcrowded classrooms and lack or and/or limited resources. Despite plentiful teachers‘ negative experiences, there are some positive aspects offered by the teaching context, the ingenuity of physical science teachers as exposed through this study.

Teachers reflected on various factors shaping their evident teaching approaches while some factors manifested during classroom teaching. In this study, it was found that Amanda and Thando had limited teaching materials especially for representing the topic of Electricity practically. These materials were not enough even for the quarter of their classrooms as they both had more than 80 learners per classroom. Therefore, the teachers only demonstrated (showing) what they had with the exception to Amanda who allowed few learners to connect the electric circuits while demonstrating to their peers.

Moreover, Thando and Amanda highlighted the issue of overcrowded classrooms in relation to available teaching and learning materials and time constraints as some of the challenges shaping their teaching approaches in the rural context. As such, to avoid spending more time on experimentation, Thando opted for demonstrations. Thando‘s phrasing of her challenges indicates constraints of her teaching context which ultimately shapes her enacted pedagogical content knowledge. This is seen when Thando stated that '…in our context you just teach this content but in actual sense a child needs to physically do this thing…but also you cannot look at 85 people (learners) in one hour so you just end up saying you have taught...‘. The teacher emphasizes the importance of learners hands-on practical experience and weighed it against her current practice where she 'just teaches‘ due to limitations such as classroom size in relation to allocated teaching time. The observed teaching approach due to large classroom size has implications on learner outcomes as Köhler (2022) associates greater class size with poorer educational outcomes. In addition to classroom size and time constraints for hands-on experiential learning, I observed Amanda writing notes, word-to-word, on the chalkboard and the notes were taken directly from the teacher‘s guide[36].

Furthermore, Amanda then shared light on the reasoning behind the observed pedagogical practice and stated that '*there is a shortage of textbooks*‘. The challenge of science textbooks shortage is referred to by Amanda as being one of the factors shaping her teaching practice. The limited accessibility and poor conditions of the available textbooks undermine the impact of this teaching and learning resource on learners‘ achievement as argued by Makori and

[36] In South Africa, teachers have to work with the general Curriculum and Assessment Policy Statement (DBE, 2011) and then are given teacher‘s guide which details the examinable content while highlighting what teachers need to focus on when teaching a particular topic. This guide gives definitions of terms, equations to be used, and also provide explanations of some scientific processes or conceptual understanding. It is different from a generic textbook.

Onderi (2014). Also, Thando alluded to the teaching time and space that shapes her teaching approaches when stating that learners in her school are fetched from afar in remote areas and are taken back home by government busses immediately after school which makes it difficult for her to involve learners in practical work during teaching. This was the reason Thando and Sipho‘s did not do practical work. The following sub-theme discusses practical work in relation to teaching context as a factor.

9.4.1. Rurality and effective practical work at loggerheads

While teachers described practical work as an important and necessary tool for teaching and learning of Electricity topic, the second sub-theme addresses the contextual limitations to effective use of practical work in rural schools as per the data of the current study. Rurality and effective practical work at loggerheads focuses on rural contextual factors including knowledge of learners that shapes physical science teachers‘ pedagogical practices in relation to practical work. Also, teachers reflected on the active role of rural context as one of the contributory factor shaping the practical work experience and eventually their pedagogical practice in science classrooms. In line with factors listed in literature, the findings of this study also indicate that classroom size; unavailability of science laboratory apparatus; and time constraints were the major barriers towards implementation of practical work when teaching Electricity (Fisher, 2010; Heeralal, 2014).

Firstly, teachers reflected on the overcrowding in their science classrooms as one factor hindering the effective practice of practical work. Thando said,

> since there are 85 learners, if I can involve each and every one then it will be havoc so let me just make them remember what they see so I‘ll go to the ‘remember route‘ because the involvement part, ooooooh

The above excerpt suggests that Thando has accepted her context and what she can or cannot do with regards to teaching and doing practical work to develop learners‘ conceptual understanding. However, the limited engagement with practical work could affect learners‘ performance in the examination because the Department of Basic Education (DBE) include question that requires application of what learners have been taught. In that case, learners could remember doing the concept in class but fail to apply the knowledge to solve a problem, which could explain the poor performance in topics such as Electricity. The grade 10 CAPS Physical Sciences places greater emphasis on the use of practical work as a teaching as well as an assessment tool (DBE, 2011; Festile, 2017). According to Hartley (2014), the role of practical work in South Africa is underestimated, especially by the teachers from previously disadvantaged schools, which include rural schools. While the author did not provide the motive, it is still important to understand teacher‘s reasons for lack and/or limited use of practical work, irrespective of knowing it is part of the examination. As noted in the above quotation, and was also mentioned by Amanda, having 85 learners in class made it difficult for her to conduct practical work, a reason Amanda arranged the 4 learners into two groups for demonstration purposes in lesson 2.

Additional to the overcrowding issue is the infrastructure and resources to do practical work. In this study, all the schools had laboratories with limited apparatus. One school (Sipho‘s) do not use the science laboratory for practical work sessions but it is used as a Grade 12 classroom for all subjects and Sipho asserted to having old apparatus but I did not see them. Another school (Thando‘s) had old apparatus, and one school (Amanda‘s) had the new apparatus though limited for her classroom size. With 85 learners and the limited available lab apparatus for the experiments, it is close to impossible to conduct hands-on practical work for Amanda and Thando. Sipho stated that "we do have, but they‘re old (apparatus). They are the older model and they are not so user friendly". This is one of the disadvantages for rural schools that their science resources are outdated, and some schools‘ budget prioritises other important things than buying recent resources. When the apparatus are available, they are usually small for all the learners to see during demonstration, either in class or laboratory. It means practical work will have to be organized for two days in small groups and ensure that all learners can see, which could be time consuming.

Moreover, Amanda said ―…so with this large group it takes time because you must attend this group, then late you will run short of apparatus‖. According to Festile (2017) it appears from the findings that teachers‘ decisions to use practical work depended on various factors, some of which include availability of resources, teachers‘ perceptions of their learners, and teacher‘s attitude towards innovation. Other researchers (Muwanga-Zake, 2001; Rogan, 2007; Kay, 2014) acknowledge that doing practical work is not significantly dependent on whether teachers have physical resources (e.g. laboratories, science apparatus or portable laboratory stations). Instead teachers that are motivated to do practical work will find ways to do so even in the most poorly resourced of schools, and those who are not motivated will not do practical work even when they have access to the best of resources.

Another important factor that influences practical work practices is the idea of contextual time constraints. To expound on this idea, Thando stated that,

> Uhm, fortunately for me I have a lab. Most schools around here do not have a lab and I am not talking about the kits but the laboratory itself. I am fortunate to have one and kits which were bought for me so I consider myself lucky. So as much as the time and space hinder us from doing a lot of practical work that we could do if the cases were different because one of the things that disturb us is that our children are collected from afar in remote areas to this school by buses[37] and when the school is over for the day, they have to be taken back home by buses so it is not easy to have extra classes with those learners. So, practical work always needs an extra class because you still need to finish the curriculum.

In the above quotation Thando considered herself fortunate and lucky for having a laboratory and the materials but time constraints for her and her learners is a challenge. It is evident that time constraints for her are in two levels: (1) curriculum time constraints, and (2) time-space constraints. Thando revealed lack of time availability as a practical challenge affecting her minimal integration of practical work, mostly at demonstration level in the classroom. Part of the reason for this time constraint is curricular coverage as she had to rush through the curricular, making sure that all concepts to be covered are taught before the examination. Considering Sipho‘s pace during the lessons, use of examination guide, and lack of demonstrations, it could be argued that time constraints and completing the syllabus before examination influenced their pedagogical approaches, including practical work. The response illustrated the point: Sipho said, "you end up saying what they‘re supposed to write (exams), meaning you‘re telling it as it is, for them to understand theory, but there wouldn‘t be a clear understanding".

Furthermore, the DBE (2011) encourages problem solving by means of practical investigations and learners‘ knowledge of problem solving approaches is required, and is concerning if teachers overlook such important skills in science education. Kay (2014) posit

[37] For the three participating schools, learners are fetched from different residential areas by buses (usually far in terms of kilometres from school). Of importance is that these buses operate at specific time intervals. For example, during data collection period, I observed that around 7:00am the buses are fetching learners from certain collection points and drops learners around 7:30am to school. After school hours, between 14:45-15:00pm the busses now takes learners back to collection points – residential areas. The busses only operate from Monday to Friday. The bus system referred to above falls within the KZN Learner Transport Policy which is the initiative of the KZN DoE as gazetted in 2020 (KZN BoE, 2020) even though in the abovementioned three schools, this project started in 2017.

that science practical work is a strategy a teacher may employ to facilitate the learning of scientific concepts, to develop the skills of identifying different types of variables, data handling, amongst others. Even though practical work could be a teaching strategy, with the various rural contextual factors, some teachers do not think of practical work as a strategy, irrespective of awareness that it is part of examination.

9.4.2. Teaching for assessment: Assessment-driven pedagogy

It is an uncontested fact that ―teaching involves assessment‖ (Rea-Dickins, 2004, p. 249) but as to what extent assessment is used *in* and/or *for*[38] teaching is of interest for this sub-theme. Amanda and Sipho taught towards examination. This approach is also argued by Khisty (1993) that teachers instill memorization rather than engaging with learners for science meaning-making. Interestingly, irrespective of participant teachers being trained in a university or college context; chalk and talk, and Question and Answer Teaching Approach (QATA) appeared dominant in all participant teachers. Although all teachers involved questions and answers in their teaching, there was very little probing of, and working with learners' ideas. However, the reason for this dominance could be the lack of resources (visual representations) for Sipho or insufficient resources for Thando and Amanda. Although QATA might serve a good purpose in the teaching and learning of physical science, but it presented the topic of Electricity as an abstract and theoretical instead of being a practical topic.

Nzoka and Orodho (2014) assert that good teachers are skilled not only in instructional methods, but also in evaluation and assessment practices that allow them to gauge individual student needs. Teachers should have expertise with aligning curriculum to assessment and keeping subject matter aligned to the intended curriculum, and without adequate content knowledge, well thought-of pedagogical knowledge and purposeful assessment in the subject, this often proves to be difficult. Evident from both teacher's reflections and classroom observations, assessment played an integral part of teachers' pedagogical approaches to Electricity topic. For example, Sipho was the only teacher who taught about factors affecting resistance and he reflected during VSRI that ―these are the part of curriculum, they must be covered. Usually they ask them in the multiple choice questions of the exam‖. To explain further his teaching using classroom activities, Sipho during VSRI argued that activities

[38] For this study, assessment in teaching refers to teacher pedagogical practices where assessment is used to support the teaching and learning processes, while assessment for teaching refers to teacher pedagogical practices where assessment is used as a tool to teach rather than supporting the teaching.

―helps them (learners) for practice … or for them to see themselves if they are following on what the teacher is doing and for me to see if they are able to do it‖, hence Sipho ―start with corrections and then the lesson of the day‖ when teaching.

Furthermore, most Electricity concepts especially electric circuits were given more assessment with limited focus on explaining processes, skills and content but content application through assessment. For example, Amanda‘s lesson 3, episodes 1-3, Amanda did not explain the series and parallel circuits including equations for resistance, current, and voltage but gave classroom activities for learners to learn through for the whole lesson. Also, Sipho‘s lesson 3 and Thando‘s lesson 4 focused on electric circuit calculations. It is therefore evident that all participant teachers adopted assessment-based pedagogy in their lessons on the topic of Electricity. Thando and Sipho adopted the approach of questioning without pointing a specific learner to give a response. This is discouraged by Chourdhry (2017) who mentions that this leads to dominance of some learners while other are left behind. Amanda was also found wanting of this practice but she would call learners by names especially when there is no response to her question. Where learners responded, teachers often confirmed learner response and limited extended feedback was given especially by Thando and Amanda on the electric circuits.

The above findings support the previous research findings by Menoe (2005) that in most South African classrooms teaching is teacher-centred with an emphasis on question and answer exchange, written exercises and tests. All teachers frequently used question and answer teaching approach. Of concern however, was the lack of response time given by Amanda and her consistent responses to her own questions. Where learners responded to teacher‘s questions, little or no probing of learner‘s understanding was done by teachers such as Amanda and Sipho mostly. Gunstone (2008) also argues that greater emphasis is put on calculations rather than conceptual understanding.

Moreover, teachers used different assessment instruments including worksheets, previous examination papers and classwork activities from textbooks. Of concern, was when learners were given homework activities individually with superficial responses or corrections by teachers. Consider for example, whether homework or classwork activities, Amanda provided detailed feedback to questions. This can be seen in Amanda‘s lesson 1, episodes 4 & 5; and lesson 3, episode 1. Unlike Sipho who provided superficial feedback in lesson 3, episode 1 and the teacher practice agreed with his beliefs about activities. Sipho mentioned during VSRI that "If there is a few (learners) who did not do it (homework activity), then I ignore and continue with the lesson they will catch up during the lesson". Teachers' choice of assessment tools was informed by their knowledge of instructional strategies and knowledge of assessment methods in relation to their learners and projected assessment outcomes.

The observed teachers preferred to use standard methods when assessing learners. These methods included; class exercises; homework; instructional oral questions; and demonstrations as noted above. The method choices are consistent with the exams that the Province of KwaZulu-Natal conducts since most of the teacher questions were from the examination guides and from previous examination papers. Teachers were well aware of this, and made more emphasis on examination knowledge rather than scientific process skills hence Amanda argued during VSRI that when using activities, she "use exam guidelines, no definition from the textbook", which is in line with the provincial examination standards. In the classroom observations teachers rarely allowed learners to justify their answers, explain relationships they saw, and /or predict the consequences of their ideas instead teachers moved with haste for the right answer. In line with Nappi's (2017) view of questioning, teachers used questioning to teach and to learn for themselves.

All teachers taught through the question and answer approach through using learner prior knowledge which is also recommended by Kucukozer and Kocakulah (2007) especially for use in teaching Electricity concepts that are perceived to be difficult by learners. Amanda and Thando were chief in using this approach as she kept on referring to what she would have said earlier. To exemplify this teaching approach, consider Thando's lesson 2, episode 3, she introduces Ohm's Law and its symbolic representations. In this episode, Thando asked and responded to her list of instructional questions without allowing waiting time for learners to think about and respond to the asked questions. Shanmugavelu et al. (2020) advice against this practice when warning teachers to pause talking for a moment to give learners time to think about the answers. This addressed the time constraint and teachers complying with the curriculum requirements that stipulates particular time for each topic, hence a prescriptive CAPS policy. Where learners were given an opportunity to respond, they responded with a one word answer, frequently a 'yes' answer to confirm the teacher's point of view. In this way, Thando's questioning did not develop critical thinking skills as Nappi (2017) proposes for the role of questioning in the classroom teaching. As such, meaningful participation of learners was not encouraged by Thando, even though using questioning as her teaching tool.

Similarly, in his lesson 1, episode 1, Sipho guided learners through a series of instructional questions towards the target concept of electric current. In this episode, the teacher confirmed learners‘ prior knowledge of power sources by giving waiting time. When an incorrect response by learners was given, the teacher rephrased the question for more clarity for accessibility to the learners. While this is commendable to elucidate the intent of the question for learners (Tofade et al., 2013), it was concerning that Sipho‘s questions were examination centred and learners were reading from the teacher‘s examination guide that was given by the teacher for learners to refer to while he was teaching. Thus, even though Sipho continued to draw from learners‘ prior knowledge of electrostatics in making a link to differentiate between charges in electrostatics and those in electric current, the examination focused teaching approach did not guarantee learners‘ scientific understanding of the concepts as they read through the guide to respond to teacher‘s questions. Similar to Thando, Amanda also asked and responded to some of her questions without giving learners a waiting time. Such practices denied learners an opportunity to engage with questioned content for development of critical thinking skills (Nappi, 2017).

Apart from the observed teacher approaches to classroom activities, teachers also indicated why they use assessment the way they do during teaching. In her explanation of how she teaches the topic of Electricity, Amanda states that,

> In this group I have discovered that when you give them classwork, it happens that you have explained the topic, give them homework only to find that they are doing it on their own. Learners rely mostly on books but what I can say is that I do see some misconceptions of which we need to attend to, that is why I always have to go back again and re-explain the concepts. At times I‘ll ask them questions but they are unable to answer them so I would have to go back to that particular topic.

Amanda asserted that she teaches content first and then give learners a classwork or homework to do. Interestingly, it appears to be a shock to Amanda that learners sometimes use their knowledge supposedly learnt in class to respond to classwork or homework activities because they assumingly did not consult textbooks. As such, misconceptions about the already taught concepts become evident in learners‘ work. Once such misconceptions are observed the teacher then re-explain the misconceptualised content. In this instant, Amanda‘s utterances suggest that assessment is her primary tool to check understanding and possible misconceptions. The platform provided by Amanda for her learners to identify, confront and break down misconceptions as well as helping them reconstruct and internalize their knowledge is supported by Chian (2020)

Moreover, a time constraint in relation to assessment and curriculum coverage was highlighted by teachers. Thando revealed "Eh! You see sometimes you can give them extra work but they don't do it. You want them to do the extra work but time doesn't allow…". According to Thando, sometimes her learners failed to do the extra work given due time limitations during normal school hours and as discussed in theme 1 above that it impossible for Thando to hold classes after normal school hours due to learner transportation. As such, without enormous assessment tasks, teachers feel that learners are not thoroughly prepared for final examination. Thando argued, "…the more you give them activities, the more practice they have. The best thing is individual attention but it is impossible for us. In this instance, more assessment tasks are equated to good learner practice which will in turn lead to improved learner performance in examinations. With the idea that sometimes learners fail to do the 'extra work' given, Thando believed that learners would have been encouraged easily if the teacher were to use a one-on-one approach in the classroom.

Additionally, to justify the use of assessment driven pedagogy, Sipho asserted ―In electricity it was mostly calculations so they had to practice. In electric circuits they do make sense because they can be proven in any way mathematically‖. Sipho viewed the related concepts of electricity as involving mostly calculations and as such content explanation was not prioritized but practice was with the hope that learners develop the skills required to solve the mathematical problems involved in electricity-related concepts. This perspective of the teacher was also evident in his classroom teaching of electricity-related concepts. To be precise with the used assessment questions, Amanda enunciated "I also use the previous question papers to help them. If they know how they are tested it becomes easier for the task that they are going to write and mid-year exams".

Additional to the textbook questions, all three teachers were observed using previous question papers in their teaching of Electricity. According to Amanda above, the previous question papers are to help learners understand how they are tested for any classroom assessment including examination purposes. This view into assessment and teaching suggests teaching for examination as opposed to teaching for conceptual understanding. Moreover, Sipho affirmed that they "work harder in a way that learners should be able to understand and answer questions" mostly in the examination. Even though understanding is mentioned by

Sipho but answering of questions correctly is prioritized because "At the end of the day we check their understanding through performance, mostly in assessment" Sipho expounded. I summarise the discussed pedagogical approaches according to individual teachers in Table 19.

Table 19

Summary of teachers' pedagogic approaches

Teacher	Lesson	Teaching Approaches					Communicative Approaches
		General approaches		Resources	Representations		
Amanda	1	Chalk &Talk	Q & A	Textbook / Learners writing on the chalkboard	Demonstration (electric circuit components)	Symbolic & sub-microscopic	Interactive / Authoritative
	2	Chalk &Talk	Q & A	Textbook	Demonstration (circuit connection)	Symbolic & sub-microscopic	Interactive / dialogic
	3	Chalk &Talk	Q & A	Textbook / Tasks	Symbolic		Interactive / dialogic
Sipho	1	Chalk &Talk	Q & A	Textbook / Worksheet / Task	Symbolic / Analogies	Sub-microscopic	Interactive / Authoritative
	2	Chalk &Talk	Q & A	Textbook	Symbolic	Sub-microscopic	Non-interactive / authoritative
	3	Chalk &Talk	Q & A	Textbook / Worksheet	Symbolic	Sub-microscopic	Interactive / Authoritative
Thando	1	Chalk &Talk	Q & A	Textbook	Symbolic / Sub-microscopic	Analogical link-making	Interactive / Authoritative
	2	Chalk &Talk	Q & A	Textbook	Demonstration (electric circuit components)	Symbolic	Non-interactive / dialogic
	3	Chalk &Talk	Q & A	Textbook	Symbolic	Sub-microscopic	Interactive / authoritative
	4	Chalk &Talk	Q & A	Textbook	Symbolic	Sub-microscopic	Non-interactive / authoritative

Note: Q & A = Question and Answer

9.5. Chapter summary

Though there are some similarities in how teachers approached the teaching of Electricity topic, all three teachers taught the topic differently. These differences are observed from the pedagogical tools teachers used and how they used these tools to teach the topic. When teaching the topic of Electricity, Sipho moved between the chalkboard, textbook (examination guide), and exam papers. Unlike Sipho, Amanda moved forward and backwards between the demonstrations, chalkboard, and textbook. The reason she moved backwards and forward was because she was forced by explanations of certain concepts that links to calculations, demonstration and oral explanations while ensuring learners' understanding of the interrelationship between the concepts, the calculation and how they all work in reality through demonstrations. Lastly, Thando moved forward and backwards between chalkboard, textbook and demonstration for the first two lessons especially where components of an electric circuit were concerned. In these two lessons, Thando started by explaining theoretically the components and then demonstrated the components in the second lesson. Then, Thando moved between textbook and chalkboard including calculations in the last two lessons.

Moreover, the findings of this study indicates that teacher talk dominated classroom communication, as teachers controlled classroom talk through the use of lecture method for teaching; implicitly silencing learners not to respond to questions or raise any question during teaching; and the use of English as LOLT which learners seemed uncomfortable with especially in Amanda and Sipho's classrooms as they asked and responded to questions through their mother tongue language (IsiZulu). While the talks of physical science being a practical subject resonates (Kibirige & Maponya, 2021) and continues to reverberate within the science community of practice, it still remains rhetorical in many rural South African schools as indicated by the findings of this case study. Physical science teachers used or valued practical work more for the teaching of Electricity topic. However, contextual limitations and other challenges made it difficult for teachers to administer practical work effectively despite their perception of practical work as a major and important teaching approach for teaching the topic of Electricity for understanding. Findings of this study further revealed that some teachers find it difficult to explain some concepts and content skills of Electricity topic which in turn puts a strain on learners as they fail to satisfactorily interpret and answer content questions during Electricity topic lessons. The upcoming chapter presents the implications of the discussed findings of this study, recommendations for future research and conclusion.

CHAPTER 10

Re-imagined Electricity topic teaching in rural secondary schools: Conclusion and Recommendations

10.1. Introduction

The study explored Grade 10 rural physical science teachers�ghp pedagogical approaches to the Electricity topic with three teachers at three different school sites in Vryheid town, KwaZulu-Natal Province. The overarching purpose was to describe and critically analyse teachers‘ pedagogical approaches to the Electricity topic in rural physical science classrooms, and contribute knowledge to the existing education physical science research. In addition, the factors that shape teacher‘s approaches were interrogated and discussed. The study sought to address the following main research question: ***How do Grade 10 rural physical science teachers teach the Electricity topic?*** And to help answer this main research question, the following sub-questions guided this exploratory study:

1. What are the Grade 10 physical science teacher‘s pedagogical approaches during the Electricity lessons?
2. What are teachers‘ pedagogical reasoning for the observed pedagogical approaches during the Electricity lessons?
3. What are the factors that influence teacher‘s pedagogical approaches to the Electricity topic in Grade 10 science classrooms?

The tsPCK components and PLM‘s first two Forms helped to access the nature of teachers‘ pedagogical approaches. I used the five tsPCK components and the two Forms of PLM and their approaches that were discussed in chapter 3 to analyse and unearth the nuances of teacher‘s pedagogical approaches. Interestingly, tsPCK also helped to understand teachers‘ pedagogical reasoning. The findings and their meanings, and nuances around the teaching of Electricity topic in rural physical science classrooms were discussed in chapters‘ six to nine. This chapter presents the summary of the findings, recommendations, strengths and limitations of this study, and directions for future research on teaching and learning Electricity topic in rural South African schools. The following section reflects on the research questions of this study in relation to the findings discussed in chapters‘ six to nine.

10.2. Summary of the findings

Research questions for this study were outlined in Chapter 1 and guided what was analysed from classroom observations, followed up through video stimulated-recall interviews, and in individual semi-structured interviews. This section provides details of how Mavhunga's (2012) tsPCK and Scott et al.'s (2011) PLM unlocked rural teachers' approaches to Electricity topic. From the Mavhunga (2012) and Scott et al. (2011) alongside communicative approaches and patterns of discourse, an interesting and solid link was observed when teachers used links to support knowledge building and promote continuity to engage with difficult concepts to teach and learn in Electricity topic and make links to demonstrate concepts continuity by referring to learner prior knowledge (LPK) and through using teacher's curricular saliency (CSA) and conceptual teaching strategies (CTS). Notably for this study, though visible in the classroom practice, some aspects of teacher's tsPCK were exposed during VSRI while PLM mostly guided the classroom practice analysis. This relationship in teachers' knowledge skills is presented in Figure 12 below.

Figure 12

Teacher's tsPCK to support knowledge building

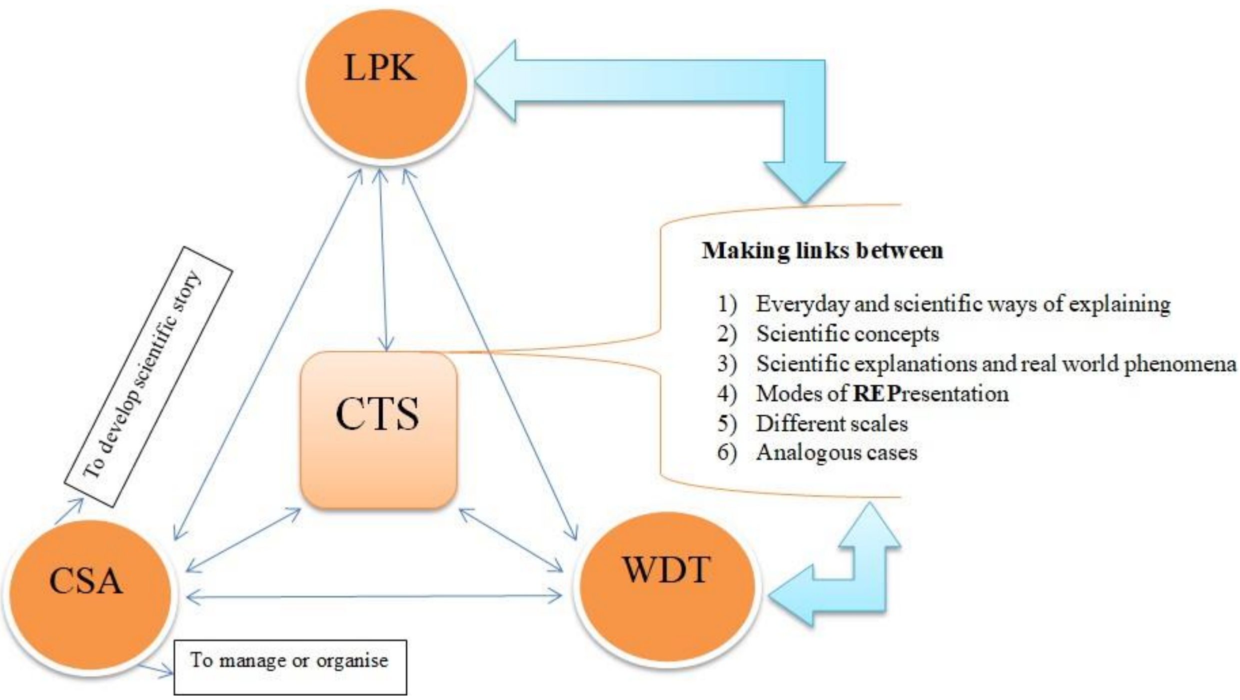


Figure 12 diagrammatically demonstrates physical science teachers‘ classroom practices from the lens of tsPCK and PLM‘s perspectives. The figure shows how different aspects of tsPCK were interlinked with PLM‘s aspects of the framework to contribute to one gelling framework for this study. The following discussion reflects on research questions for this study which were answered from the tsPCK to support knowledge building‘s perspective and I begin reflecting on teachers‘ pedagogical approaches and then factors that shaped teachers observable pedagogical approaches.

10.2.1. Supporting topic-specific knowledge building: Rural teacher's pedagogical approaches for Electricity topic

All three teachers taught the same topic differently, though there were similarities in some teaching aspects. The findings indicate that teachers used different modes of explanations to support Electricity topic knowledge building, specifically a combination of link-making between scientific explanations and real world phenomena; everyday and scientific ways of explaining; Analogical link-making; scientific concepts through equations; different modes of representations, which dominated all lessons especially the symbolic level of representations. While these approaches played an important role in the lessons, however teachers experienced challenges in making explicit links in moving between the different scales and levels of representations to explain concepts. In few lessons, Amanda and Thando moved from symbolic including diagrammatic to macroscopic representations, and rarely moved to the level of sub-microscopic representations. Interestingly, Sipho only focused on the symbolic level of representation of the topic. While making pedagogical links, teachers referred to learners‘ prior knowledge but did not use it effectively to develop scientific knowledge building, where used it was often used for teacher‘s confirmation of their knowledge or the knowledge that they supposedly taught.

Notwithstanding some pedagogical limitations, teachers used context-sensitive analogies to teach the Electricity topic. Consequently, the teachers‘ explanation of difficult concepts and demonstrations of practical work resulted to more confusion. This is concerning because Electricity topic is already regarded as a difficult topic due to abstraction of concepts like current, voltage (potential difference), emf, resistance, etc even though it is applicable and observable in the real world phenomena. Also, teachers used question and answer teaching approach where they frequently initiated conversation through questions, either responded to their questions or allowed learners to provide short answers (mostly yes or no) followed by teachers confirmation of responses. This approach led to classroom talk being closed evaluative and feedback authoritative. This practice led to teachers teaching Electricity topic and concepts for their own learning.

10.2.2. Modes of Representations to teach Electricity topic

Teachers relied mostly on representations when teaching Electricity topic. The findings indicate that symbolic level of representation in the form of equations, diagrams, and electric circuit symbols, dominated all teachers' lessons. The macroscopic level of REP dominated three lessons from two teachers in the form of demonstration and I reflect on this aspect in the subsequent section. The findings suggest that while teachers could work with symbolic and macroscopic levels of representations, their teaching revealed limited inter-connectedness between these levels of representations including sub-microscopic level of REP, which rarely featured in teachers' lessons. Teachers use of symbolic representations focused on proceduralisation (following steps during mathematical calculations), overlooking making links between the calculations and sub-microscopic and what is then observed at macroscopic level as a result of charge flow, current flow, potential difference (emf) and resistance. Therefore, all teachers used calculations (symbolic REP) predominantly as an end product instead of tools to communicate ideas of Electricity topic and use it to explain and understand the unobservable sub-microscopic nature of Electricity and in turn justify the observable nature of macroscopic level of electricity. This is concerning because DBE (2011) requires physical science teachers and learners to "demonstrate an understanding of the world as a set of related systems by recognizing that problem solving contexts do not exist in isolation" (p. 5). Interestingly, two of the three teachers taught the difficult concept of "on" and "off" of a switch through making a link between scientific explanation and real world phenomena by using a macroscopic level of representation familiar to learners.

10.2.3. Practical work in developing Electricity knowledge building

Practical work is important in teaching physical science and is prescribed for Grade 10 Electricity topic in the CAPS curriculum as one of the requirements for teachers and learners (DBE, 2011). Part of what Grade 10 teachers should demonstrate includes, how to measure emf and terminal potential difference; setting up a circuit to measure the current flowing through a resistor or light bulb and also to measure the potential difference across a light bulb or resistor; setting up a circuit to show that series circuits are voltage dividers, while current remains constant and that parallel circuits are current dividers, while potential difference remains constant, which is a prescribed practical for formal assessment in Grade 10. Of the required practical skills, one teacher was able to demonstrate how to set up a circuit even though she estimated current flow in a light bulb through comparing one and two light bulbs in series. The same teacher incorrectly demonstrated how to measure emf when she used a wrong voltmeter scale (3V) instead of a 9V for a total of 4 cells. However, this was the best rural learners could observe during this study because with a second teacher, there was no practical work even though he argued for the importance of practical for deep scientific understanding.

Similarly, the third teacher only demonstrated (showed) different components of an electric circuit while she argued for the importance of practical work in teaching Electricity topic during VSRI. Despite the importance and relevancy of practical work in Electricity topic teaching and learning, this study revealed and confirmed the difficulty of conducting hands-on practical work and teachers preference to demonstrations due to high number of learners per class, lack of and/or limited apparatus for some schools, teacher‘s limited knowledge of working with Electricity apparatus, curriculum coverage time constraints, among other factors. Therefore, findings suggest that practical work was minimally used, and where used it was not effectively used for the development of learners‘ Electricity knowledge building. Teacher‘s lack of hands-on practical work has no potential in assisting learners with practical skills relating to electric circuit connection for the development of deeper understanding.

10.2.4. Teacher’s pedagogical reasoning: Factors influencing teacher’s pedagogical approaches for Electricity topic

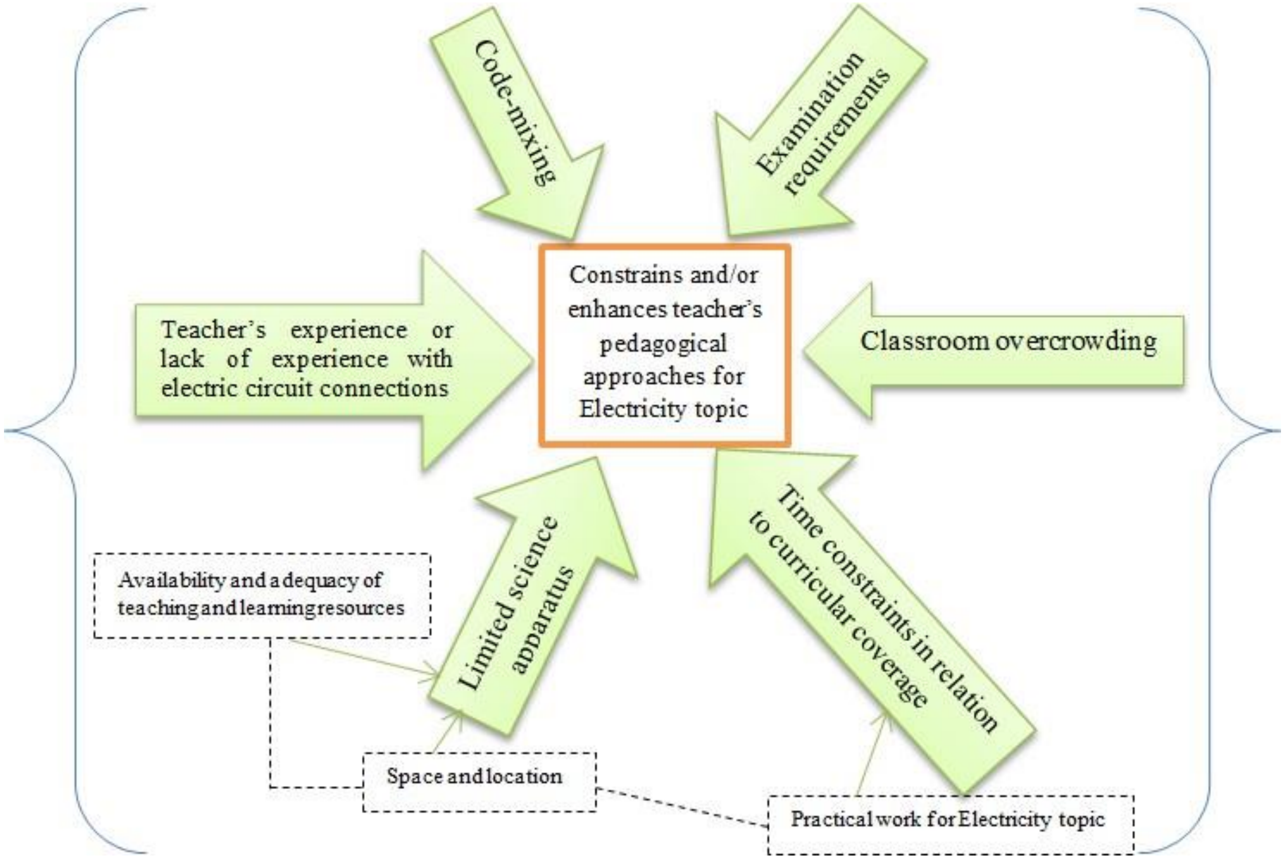
The overall findings demonstrates that teachers pedagogical approaches cannot be separated from the teaching environment where they are captured and experienced, and as such, the observed teaching was influenced by various factors ranging from context-based, learner considerations, school contextual factors, curricular factors among others. Through VSRI and semi-structured interviews, findings of this study indicate that, practical work for Electricity topic and rurality for Vryheid rural teachers are at loggerheads. Thus, rurality shaped teacher‘s pedagogical approaches for the Electricity topic. As a result, teachers were critical of time constraints in relation to curricular coverage and practical work for Electricity topic; overcrowded classrooms (over 80 learners in one classroom); limited science apparatus; and space and location hindering effective practical work for Electricity topic. Additionally, teachers revealed challenges of availability and adequacy of teaching and learning resources which negatively affected teacher effectiveness in the use of teaching methods as also observed by Bizimana and Orodho (2014). As a result, teachers theorize the Electricity topic teaching, hence teaching it to paint a picture to enable understanding due to lack of science teaching and learning resources. These are some factors that shaped and hindered effective teaching of physical science including Electricity topic in rural science classrooms.

The findings also showed that teachers teach Electricity topic for regurgitation in assessment with little emphasis on deep conceptual understanding. This related to the Department of Basic Education‘s requirements and a need for teachers to prove to the DBE‘s bureaucrats that they are teaching. As a result, teachers teach Electricity topic by following the exam guidelines and then coaching learners to be able to remember and reproduce knowledge during assessment. Interestingly, all teachers justified their usage of symbolic and macroscopic representations including demonstrations by hands, and analogies, as useful strategies for enhancing conceptual understanding of the difficult and abstract concepts of Electricity topic. Linked to what is difficult to teach and learn about Electricity topic, teachers argued for a need to constantly draw from learner prior knowledge of Electricity related concepts, knowledge skills and procedures.

Moreover, while teachers think, plan, and execute lessons, they should consider how their learners will receive the content and content skills in ways that are understandable to them within their context. The findings of this study exposed teacher‘s recognition of English language (LOLT) barriers in the classroom by using code-mixing learners‘ home language (IsiZulu) with English, especially when a scientific process, content, or skills needed clarification or when giving instructions to learners including explanation of analogies used in class. A concerning teacher‘s experience or lack of experience especially with the physical electric circuit connections including appropriate use of various electric circuit components was brought into the fore in this study. Even though, from the findings of this study, there was no clear link between teacher‘s level of content knowledge and observed pedagogical approaches, and this study did not attempt to expose this relation but teacher‘s pedagogical approaches. I have summarized and presented diagrammatically the various factors found to be influencing teachers‘ pedagogical approaches to Electricity topic for this study (Figure 13 on the subsequent page).

Figure 13

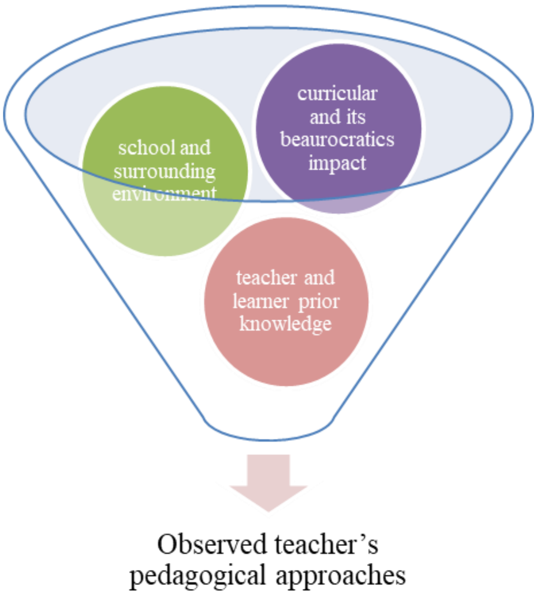
Factors shaping teacher's pedagogical approaches



These factors could contribute in leading to successfully constraining and/or enhancing learners' learning of physical science content. The factors in Figure 13 can be classified into three categories: curricular and its bureaucratic impact; school and surrounding environment; and teacher and learner prior knowledge. The categories are represented in Figure 14.

Figure 14

Categorised factors that influences teachers' pedagogical approaches



10.3. Contributions and of the study

Two key observable methodological and theoretical contributions of this study include the powerful knowledge production through video stimulated-recall interviews when used alongside classroom observation to understand science classroom practices. The second aspect is the extension of the topic-specific pedagogical content knowledge to the pedagogical link-making framework which resulted into tsPCK to support knowledge building as a theoretical and analytical lens for understanding science classroom practices. Additionally, this study contributes to the understanding of rural teachers' pedagogical approaches for Electricity topic, and the factors that influences these approaches. Furthermore, the findings of this study contributes to the rural place-based knowledge of how teachers teach Electricity topic in Grade 10, especially when considering the dominant urban-based education research that often overlooks rural teachers' experiences. This knowledge could help policy makers especially with the political agenda of rural education policies in South Africa. The knowledge of this study could also benefit physical science curriculum experts, including teacher training institutions when designing or modifying the curriculum to consider contextual factors that enhance and/or impede the quality and effective teaching and learning of physical science including the topic of Electricity in rural classrooms of South

Africa. Finally, the findings of this research might also provide baseline data to studies examining the teaching of topics such as Electricity in rural classrooms.

10.4. Limitations of the study

Given the nature of the study being a case study, the findings of this study are limited to the three teachers and three schools that were selected from the Zululand Municipality, Vryheid town in KwaZulu-Natal Province, South Africa. The study focussed on teaching approaches of the three teachers, which might be argued to represent a small sample, even though qualitative approach (thick descriptions) allows such sample. Another limitation is the exclusion of learners as participants of the study, to understand whether and how teachers‘ approaches influenced learning. While this was important, I realised that including learners was not going to be easy during the COVID-19 pandemic due to limited contact teaching sessions and limited access of researchers to schools sites during the peak of the pandemic. The limitation of conducting research within rural classrooms influenced the period in the field, because I had to travel 420 kilometers from Johannesburg to KwaZulu-Natal, and 15 to 30 kilometers between each school, as demonstrated in section 4.6.1. It was challenging for one person, and I had to request teachers to rearrange the teaching of the topic in school‘s timetable to accommodate me.

10.5. Recommendations and directions for future research

This section provides recommendations relating to teaching of Electricity topic in physical science, science teacher support and training opportunities, continuous professional development (CPD) on the use of frameworks that support strengthening of PCK & tsPCK, initial teacher education (ITE), rural education directorate and provincial department of basic education in KZN. The recommendations for future research are also discussed.

10.5.1. Recommendations for the teaching of Electricity topic

Firstly, physical science teachers need to create a conducive teaching and learning environment that encourages learners‘ participation and interest to explore the different aspects of Electricity topic. In particular, aspects, such as, macroscopic representation (connectivity of electric circuits), symbolic representations including equations and diagrams, sub-microscopic representations especially to show movement of current, and analogies for Electricity concepts should motivate learners‘ curiosity. I further recommend that teaching tasks used during teaching should go beyond the procedures to calculate values without meaning, drawing circuits but integrate application questions where learners are able to analyse, evaluate, and synthesis scientific knowledge of Electricity topic. Without overlooking the pressure from the district managers or curriculum advisors, physical science teachers should incorporate more explorative routines and employ interactive/dialogic communicative approaches to enable learners' own creation of narratives about science concepts and processes so they can also learn how to communicate scientifically during lessons for the development of a deeper scientific understanding of the Electricity concepts. The following section focuses on the recommendations

10.5.2. Recommendations for science teacher support and training opportunities

Based on the findings on working with curriculum materials including examination guidelines, I recommend training of in-service teachers on how to interpret and use the curriculum documents as resources that frames their physical science teaching. Also, intentional teacher support programs should be initiated for teacher professional development, strengthen teachers' pedagogical content knowledge, especially in-service teachers particularly those teaching in rural contexts. To avoid certain content knowledge not being taught, like in the case of Amanda where conceptual explanation of series and parallel circuits including its mathematical representation were only taught through tasks, I recommend intervention programmes that will be aimed at helping teachers bridge the content knowledge and pedagogical knowledge gaps for Electricity topic. Teachers need to be professionally developed on effective pedagogical approaches for physical science including Electricity topic, including in the rural contexts. These professional development programmes could extend to handling Electricity apparatus in a science laboratory or classroom. The professional development opportunities need to be specific, practical and truly developmental for classroom-based science teachers.

10.5.3. Recommendations for initial teacher education (ITE)

Based on the findings of teaching through ‗examination guidelines' and ‗previous exam question papers', I recommend an explicit teacher training program to focus on how to use the curriculum documents to frame and structure teachers' teaching of the contents of physical science. Also, findings of this study indicated that teachers taught for compliance as it was noted by Amanda, I therefore recommend training of subject advisors on how to support physical science teachers rather than instilling fear among teachers. I acknowledge the role of DBE in appointing subject advisors but there should be a joint intervention between DBE and teacher-training institutions to capacitate subject advisors on their role as subject advisors. ITE should consider training context sensitive teachers who will be able to adapt in any teaching context in South Africa and effectively work with available resources to promote deep scientific understanding.

10.5.4. Recommendations for continuous professional development (CPD) on the use of frameworks that support strengthening of PCK and tsPCK

Findings of this study demonstrated that some teachers find it difficult to teach Electricity topic, therefore, there is a need for future research to consolidate a model or a tool for physical science teachers on how to teach difficult topics such as Electricity topic within rural contexts characterised by limited science apparatus. Given the findings of this study, it will be beneficial to examine the impact of interventions intending to equip physical science teachers with pedagogical knowledge skills and tools in teaching physical science in rural school contexts and how to harness the contextual opportunities for the enhanced physical science teaching and learning processes. This knowledge will also help the national rural education directorate – DBE.

10.5.5. Recommendations for future research

This study exposes a need for future research to focus on physical science teaching within rural South African schools in general and the topic of Electricity in particular. Furthermore, findings of this study were derived from one district in Vryheid town. For future research, replication of this study in another district or with teachers in a different context (township / urban) could help examine teacher‘s pedagogical approaches further, particularly for the Electricity topic. Also, this study worked with three teachers, I recommend future researchers to consider larger samples which will also include learners to understand whether and how teachers‘ approaches influences learning. To counteract the challenges encountered in this study, I recommend future researchers to consider having research assistants to assist with data collection especially when researching with remote rural schools. Also, the observed teacher‘s lack of explicit, directed, and purposeful learner engagements in lessons may undermine learners' meaning-making processes. Further research in this field is still a necessity to examine how learners learn science under the current teaching conditions in rural South African schools.

10.6. Conclusion of the study

The aim of this study was not to criticize rural physical science teachers on how they teach but to unearth their current teaching practices. As such, findings of this study shed some light on what it might mean to teach a relatively difficult physics topic within rural contexts of South Africa, the lessons of what we can learn from Vryheid rural physical science teachers and what could possibly be done to enhance their teaching of science and in turn learners‘ comprehension of the subject. This study gave insights on rural physical science teachers‘ pedagogical approaches as well as numerous factors that shape teachers approaches in rural science classrooms. Moreover, the findings demonstrated that physical science teachers are faced with multiple challenges in effectively teaching physical science including Electricity topic in rural schools. Also, it was concerning to observe conditions that rural South African teachers teach under. Teachers must find ways of teaching to their best ability in the contemporary rural South Africa.

Despite limited teaching context, some teachers are good teachers and they exposed their teaching skills through this study while some teachers‘ focuses on rote-learning and are limited to prescribed examinable processes of the curricular rather than teaching content knowledge for deep scientific understanding. What stood out for me in this study was that teaching physical science in the contemporary rural South African classrooms is challenging but teachers put their efforts to teach the subject effectively regardless of contextual limitations. Through this research, I have learnt the power of VSRI when studying teacher practices. VSRI served as an important reflexive tool for teachers in this study because teachers thought of new and improved teaching strategies to employ after engagements through VRSI. Given its importance however, if I were to do this study again, I would conduct VSRI immediately after each observed classroom lesson to flash out possibilities of teachers not remembering why certain approaches were chosen and enacted the way they were. However, I was encouraged by listening to teachers during Electricity lessons and their teaching experiences of the topic as observed in the classrooms and narrated during semi-structured interviews. The current study hopes to have expanded new possibilities for more science education research within rural areas and schools. Above all, doing this research study was a worthwhile experience.

List of references

Aboagye, G.K, Ossei-Anto, T., & Ampiah, J. (2018). Combining inquiry-based hands-on and simulation methods with cooperative learning on students‘ learning outcomes in electric circuits. *American Journal of Educational Research, 6*(8), 1172–1181.

Adeoye, F. (2010). Effects of problem-solving and cooperative learning strategies on senior secondary school students‘ achievement in physics. *Journal of theory and practice in education*, *6*(2), 235-266.

Akarsu, B. (2017). Students‘ Perspective on Cultural Issues and Views of The Nature of Science. *Journal of European Education*, *7*(1), 23-31.

Alexander, R.J. (2001). In any language, it‘s good to talk. Times Educational Supplement, 19 January. http://www.tes.co.uk/article.aspx?storycode=342696

Alexander, R. (2018). Developing dialogic teaching: Genesis, process, trial. *Research papers in education*, *33*(5), 561-598.

Aligo, B. L., Branzuela, R. L., Faraon, C. A. G., Gardon, J. D., & Orleans, A. V. (2021). Teaching and learning electricity—A study on students‘ and science teachers‘ common misconceptions. *Manila J. Sci*, *14*, 22-34.

Aliyu, A. A., Singhry, I. M., Adamu, H. A. R. U. N. A., & AbuBakar, M. A. M. (2015). Ontology, epistemology and axiology in quantitative and qualitative research: Elucidation of the research philosophical misconception. In *Proceedings of the Academic Conference: Mediterranean Publications & Research International on New Direction and Uncommon* (Vol. 2, No. 1, pp. 1054-1068).

Ambusaidi, A., & Al-Farei, K. (2017). Investigating Omani science teachers‘ attitudes towards teaching sciences: The role of gender and teaching experiences. *International Journal of Science and Mathematics Education, 15*(1), 71-88.

Anderson, C. (2010). Presenting and evaluating qualitative research. *American journal of pharmaceutical education*, *74*(8).

Arnold, M. and Millar, R. (1987). ‗Being constructive: An alternative approach to the teaching of introductory ideas in electricity,‘' *International Journal of Science Education, 9* (5), 553–563.

Aydin, S., & Boz, Y. (2013). The nature of integration among PCK components: A case study of two experienced chemistry teachers. *Chemistry Education Research and Practice*, *14*(4), 615-624.

Babbie, E. R. (2011). *Introduction to social research*. Wadsworth Cengage learning.

Babbie, E. R., & Mouton, J. (2007). Qualitative methods of Data sampling. *The practice of social research*, *7*, 187-193.

Bakhtin, M. M. (1981). The Dialogic Imagination: Four Essays, M. Holquist, ed., C. Emerson and M. Holquist. *Trans., University of Texas Press, Austin*.

Balfour, R. J., Mitchell, C., & Moletsane, R. (2008). Troubling contexts: Toward a generative theory of rurality as education research. *Journal of Rural and Community Development*, *3*(3), 95-107.

Ball, D. L., & Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. *Multiple perspectives on the teaching and learning of mathematics*, *4*(1), 83-104.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content Knowledge for Teaching: What makes it special? *Journal of Teacher Education, 59*, 389-407.

Bashir, S., Lockheed, M., Ninan, E., & Tan, J. P. (2018). *Facing forward: Schooling for learning in Africa*. World Bank Publications.

Beaty, W. J. (1996). What is electricity. *Retrieved April*, *14*, 2007.

Beeland Jr, W. D. (2002). Student engagement, visual learning and technology: can interactive whiteboards help?.

Bernardo, J. (2020). PH ranks last among 58 countries in Grade 4 math, science: Study. *ABS-CBN News*. Retrieved from https://news.abs-cbn.com/news/12/09/20/ph-ranks-last-among-58-countries-in-grade-4-math-science-study

Bernstein, B. (1996). Pedagogy, symbolic control & identity theory. London: Taylor and Francis.

Bilbao-Osorio, B., Dutta, S., & Lanvin, B. (2014). The global information technology report 2014: Rewards and risks of big data. In *World Economic Forum* (pp. 1-369).

Binnie, A. (2001). Using the history of electricity and magnetism to enhance teaching. *Science & Education*, *10*, 379-389.

Bishop, K., & Denley, P. (2007). *Learning Science teaching: Developing a professional knowledge base*. UK: McGraw-Hill Education.

Bizimana, D. B., & Orodho, J. A. (2014). Teaching and learning resource availability and teachers‘ effective classroom management and content delivery in secondary schools in Huye District, Rwanda. *Journal of Education and Practice*, *5*(9).

Bloch, G. (2008). Fixing education is a 30-year task. Available: http://www.iol.co.za/news/southafrica/fixing-education-is-a-30-year-task-1.392870?ot=inmsa.ArticlePrintPageLayout.ot.

Boateng, S. & Mushayikwa, E. (2022). Teaching electricity and magnetism to high school physical science learners: The effectiveness of learning style-based instructions. *Int. Sci. Res. J*, *78*.

Bradley, J. D., & Moodie, P. (2021). A systemic approach to teaching and learning about electrical cells and circuits using two big ideas of science. *African Journal of Chemical Education*, *11*(1).

Bradley, J., Khulu, S., Moodie, P., & Mphahlele, M. (2019). Using microscience kits to address a student-teacher misconception in electric circuits: at the interface between chemistry and electricity. *African Journal of Chemical Education*, *9*(3), 37-49.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77-101.

Burde, J. P., & Wilhelm, T. (2020). Teaching electric circuits with a focus on potential differences. *Physical review physics education research*, *16*(2), 020153.

Burde, J. P., Weatherby, T. S., & Wilhelm, T. (2022). Putting Potential at the Core of Teaching Electric Circuits. *The Physics Teacher*, *60*(5), 340-343.

Caballero, D., Araya, R., Kronholm, H., Viiri, J., Mansikkaniemi, A., Lehesvuori, S., & Kurimo, M. (2017). ASR in classroom today: Automatic visualization of conceptual network in science classrooms. In Lavoué É., Drachsler H., Ver bert K., Broisin J., Pérez-Sanagustín M. (eds) *Data Driven Approaches in Digital Education: 12th European Conference on Technology Enhanced Learning, EC-TEL 2017, Tallinn, Estonia, September 12–15, 2017, Proceedings 12* (pp. 541-544). Springer International Publishing.

Caleon, I. S., Tan Y S. M., & Cho Y. H. (2017). Does Teaching Experience Matter? The Beliefs and Practices of Beginning and Experienced Physics Teachers. Research in Science Education, 48(1), 117-149. doi: 10.1007/s11165-016-9562-6

Caleon, I. S., Tan, Y. S. M., & Cho, Y. H. (2018). Does teaching experience matter? The beliefs and practices of beginning and experienced physics teachers. *Research in Science Education*, *48*(1), 117-149.

Carlson, J. Daehler, K.R. (2019). The Refined Concensus Model of Pedagogical Content Knowledge in Science Education. In *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science*; Hume, A., Cooper, R., Boroswki, A., Eds.; Springer: Singapore; pp. 77–92.

Carrejo, D. J., & Marshall, J. (2007). What is mathematical modelling? Exploring prospective teachers' use of experiments to connect Mathematics to the study of motion. *Mathematics Education Research Journal*, *19*(1), 45–76.

Carrim, N., & Soudien, C. (1999). Critical antiracism in South Africa. *Critical multiculturalism: Rethinking multicultural and antiracist education*, 153-171.

Chabay, R., & Sherwood, B. (2006). Restructuring the introductory electricity and magnetism course. *American Journal of Physics*, *74*(4), 329-336.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2008). An evaluation of a teaching intervention to promote students' ability to use multiple levels of representation when describing and explaining chemical reactions. *Research in science education*, *38*, 237-248

Chasteen, S. V., & Pollock, S. J. (2008, October). Transforming Upper-Division Electricity and Magnetism. In *AIP conference proceedings* (Vol. 1064, No. 1, pp. 91-94). American Institute of Physics.

Chatoupis, C. (2016). Planning physical education lessons as teaching ―episodes‖. *Strategies*, *29*(2), 20-26.

Chen, C., Sonnert, G., Sadler, P. M., & Sunbury, S. (2020). The impact of high school life science teachers' subject matter knowledge and knowledge of student misconceptions on students' learning. *CBE—Life Sciences Education*, *19*(1), ar9.

Chen, J. L., & Mensah, F. M. (2018). Teaching contexts that influence elementary pre-service teachers' teacher and science teacher identity development. *Journal of Science Teacher Education*, *29*(5), 420-439.

Cheng, M., & Gilbert, J. K. (2009). Towards a better utilization of diagrams in research into the use of representative levels in chemical education. *In Multiple representations in chemical education* (pp. 55-73). Springer Netherlands.

Chian, H. M. (2020). Targeting Misconceptions Using Socratic Questioning.

Childs, P. E. (2006). The Problems with Science Education: ―The more things change, the more they are the same‖. In *Proceedings of SMEC Conference. http://chemistrynetwork. pixel-online. org/data/SMO_db/doc/20_peter% 20childs% 20problems% 20with% 20science% 20eductaion. pdf*.

Choi, J & Hannafin, M. (1995). Situated Cognition and Learning Environments: Roles, Structures, and Implications for Design

Coetzee, M. (2021). *First Year University Students' Conceptual Understanding of Electric Circuits* (Doctoral dissertation, University of Pretoria (South Africa).

Cohen, L. M., & Manion, L. l. & Morrison, K. (2007). *Research methods in education*, *6.* London: Routledge.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). London: Routledge

Condy, J., & Phillips, H. N. (2020). How are we really teaching our students? A paradox in pedagogy. *South African Journal of Higher Education*, *34*(2), 210-229.

Connor, M. C., & Shultz, G. V. (2018). Teaching assistants' topic-specific pedagogical content knowledge in 1 H NMR spectroscopy. *Chemistry Education Research and Practice*, *19*(3), 653-669.

Creswell, J. W. (2007). *Educational research: Planning, conducting, and evaluating quantitative*. *New Jersey: Upper Saddle River*.

Creswell, J. W. (2009). Editorial: Mapping the field of mixed methods research. *Journal of Mixed Methods Research*, *3*(2), 95-108.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.

Creswell, J.W. (2012). *Education Research: Planning, conducting, and evaluating quantitative and qualitative research* (4th Ed). USA, Pearson Education Inc.

Dagher, Z. R. (1995). Analysis of Analogies Used by Science Teachers. *Journal of Research in Science Teaching*, *32*(3), 259 - 270.

Dahal, N., Luitel, B. C., & Pant, B. P. (2019). Understanding the use of questioning by mathematics teachers: A revelation. *International Journal of Innovation, Creativity and Change*, *5*(1), 118-146.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective Teacher Professional Development. Palo Alto, CA: Learning Policy Institute. Retrieved from https://learningpolicyinstitute.org/product/teacher-prof-dev

Davidowitz, B., & Rollnick, M. (2011). What lies at the heart of good undergraduate teaching? A case study in organic chemistry. *Chemical Education Research and Practice*, *12*, 355- 366.

De Carvalho, R. (2019). Embodied learning and multimodality in science education: teachers‘ perceptions of teaching electrical circuits, their diagrammatic symbols, physical components and functions through multisensory approach. *Research in Teacher Education*, *9*(1), 12-18.

Deetz, S. A. (1982). Critical interpretive research in organizational communication. *Western Journal of Communication (Includes Communication Reports)*, *46*(2), 131-149.

Dega, B. G. (2012). *Conceptual change through cognitive perturbation using simulations in electricity and magnetism: a case study in Ambo University, Ethiopia* (Doctoral dissertation, University of South Africa).

Dega, B. G., Kriek, J., & Mogese, T. F. (2013). Categorization of alternative conceptions in electricity and magnetism: The case of Ethiopian undergraduate students. *Research in Science Education*, *43*, 1891-1915.

Denzin, N.K. & Lincoln, Y. S. (2004). *Handbook of Qualitative Research.* Thousand Oaks: Sage

Denzin, N.K. & Lincoln, Y. S.(2005). *Handbook of Qualitative Research.* Thousand Oaks: Sage

Depaepe, F.,Verschaffel, L., & Kelchtermans, G. (2013). Pedagogical content knowledge: A systematic review of the way in which the concept has pervaded mathematics educational research. *Teaching and Teacher Education, 34*, 12-25.

Department of Basic Education (2021). Physical Sciences: Examination Guidelines. Pretoria. pp.1-36

Department of Basic Education (DBE). (2011). *Curriculum Assessment Policy Statement (CAPS), Grades 10–12: Physical Sciences*. Pretoria: Government Printer.

Department of Basic Education (DBE). (2016). *National Senior Certificate Examination: Diagnostic Report*. Pretoria: Government Printer.

Department of Basic Education (DBE). (2017). *National Senior Certificate Examination: Diagnostic Report*. Pretoria: Government Printer.

Department of Basic Education (DBE). (2018). *National Senior Certificate: Diagnostic Report (Part 1).* pp. 1-195.

Department of Basic Education (DBE). (2018). *RURAL EDUCATION DRAFT POLICY.*

Department of Basic Education (DBE). (2019). *National Senior Certificate Examination: Diagnostic Report*. Pretoria: Government Printer.

Department of Basic Education. (2012). *Annual Report 2011/2012*. Pretoria: Government Printer.

Department of Basic Education. (2020). Teacher Guidelines for Implementing Revised Annual Teaching Plans (ATPs): TEACHER VERSION. Pretoria: Department of Basic Education.

Department of Basic Education (DBE). (2021). *Physical Sciences: Examination Guidelines. Grade 12*. Pretoria: Government Printer.

Dhurumraj, T. (2018). *Contributory factors to poor learner performance in Physical Sciences in KwaZulu-Natal Province with special reference to schools in the Pinetown District*. (unpublished doctoral dissertation) University of South Africa. RSA

Diaz, K. V. L. T. (2017). Prior knowledge: Its role in learning. *University of the Philippines Los Baños. DOI*, *10*.

Dilber, R., & Duzgun, B. (2008). Effectiveness of analogy on students' success and elimination of misconceptions. *Latin-American Journal of Physics Education*, *2*(3), 3.

Doolin, B. (1998). Information technology as disciplinary technology: being critical in interpretive research on information systems. *Journal of Information Technology*, *13*(4), 301-311.

Dowling, P., & Brown, A. (2010). Doing Research/Reading Research. New York: Routledge.

Du Plessis, P., & Mestry, R. (2019). Teachers for rural schools–a challenge for South Africa. *South African Journal of Education*, *39*.

Duit, R., & von Rhöneck, C. (1997). Learning and understanding key concepts of electricity. *Connecting research in physics education with teacher education,* 1997-1998.

Education Policy Consortium. (2005). Emerging Voices: a report on education in South African rural communities.

Emanovský P., Gonda D. (2020) ‗Mathematical Calculations within Physics Lessons and Their Popularity Among Learners', Journal on Efficiency and Responsibility in Education and Science, vol. 13, no. 4, pp. 204-211. http://dx.doi.org/10.7160/eriesj.2020.130404

Engelhardt, P.V. & Beichner, R.J. (2004). Students' understanding of direct current resistive electrical circuits. American Journal of Physics, 72(1), 99-115.

Erinosho, S. Y. (2013). How do students perceive the difficulty of physics in secondary school? An exploratory study in Nigeria. *International Journal for Cross-disciplinary Subjects in Education (IJCDSE)*, *3*(3), 1510-1515.

Erol, M., Buyuk, U., & Onal, N. T. (2016). Rural Turkish Students' Reactions to Learning Science in a Mobile Laboratory. *Educational Sciences: Theory & Practice*, *16*(1).

Ferreira, A. P. (2014). Vygotsky and Piaget: scientific concepts. *Psychology in Russia: State of the art*, *7*(3), 24-34.

Festile, R. M. (2017). The influence of Practical Work in the teaching and learning of acids, bases and neutrals in Natural Sciences.

Fino, M. H. (2018). Challenges in teaching electrical circuit analysis to millennials. In *2018 3rd International Conference of the Portuguese Society for Engineering Education (CISPEE)* (pp. 1-4). IEEE.

Fisher, K. (2010). Technology-enabled active learning environments: An appraisal.

Fox, D. (1983). Personal theories of teaching. *Studies in higher education*, *8*(2), 151-163.

Freebody, P. (2003). *Qualitative research in education: Interaction and practice.* London: SAGE Publications.

Freire, P. (1973). Education for Critical Consciousness, New York, Seabury. *Hugh McLaughlin.*

Freire, P. (2018). The banking concept of education. In *Thinking About Schools* (pp. 117-127). Routledge.

Gabel, D. L. (1993). *Handbook of Research on Science Teaching and Learning Project*. Macmillan Publishing Company, Division of Macmillan, Inc., 866 Third Avenue, New York, NY 10022.

García-Carrión, R., Villardón-Gallego, L., Martínez-de-la-Hidalga, Z., & Marauri, J. (2020). Exploring the impact of dialogic literary gatherings on students' relationships with a communicative approach. *Qualitative inquiry*, *26*(8-9), 996-1002.

Gardiner, M. (2008). Education in rural areas. Issues in education policy, 4, 1-34.

Gass, S. M.& Mackey, A. (2000). Stimulated recall methodology in second language research. Routledge. (chapter 7)

Geddis, A. N., & Wood, E. (1997). Transforming subject matter and managing dilemmas: A case study in teacher education. *Teaching and Teacher Education, 13*(6), 611–626.

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: results of the thinking from the PCK summit. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 28–42). New York, NY: Routledge.

Gopaul, M. (2009). *The significance of rural areas in South Africa for tourism development through community participation with special reference to Umgababa, a rural area located in the province of KwaZulu-Natal* (Doctoral dissertation).

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education.* New York: Teachers College Press.

Guisasola, J. (2014). Teaching and learning electricity: The relations between macroscopic level observations and microscopic level theories. *International handbook of research in history, philosophy and science teaching*, 129-156.

Gunckel, K. L., Covitt, B. A., & Salinas, I. (2018). Learning progressions as tools for supporting teacher content knowledge and pedagogical content knowledge about water in environmental systems. *Journal of Research in Science Teaching*, *55*(9), 1339-1362.

Gunstone, R., Mulhall, P., & McKittrick, B. (2009). Physics teachers‘ perceptions of the difficulty of teaching electricity. *Research in Science education*, *39*, 515-538.

Heeralal, P. J. H. (2014). Barriers experienced by natural science teachers in doing practical work in primary schools in Gauteng. *International Journal of Educational Sciences*, *7*(3), 795-800.

Heeralal, P. J. H., & Dhurumraj, T. (2016). Factors that contribute to poor learner performance in physical sciences in KwaZulu-natal Province with special reference to schools in the Pinetown district. *International Journal of Educational Sciences*, *14*(3), 304-317.

Hieggelke, C. J., Maloney, D. P., O‘Kuma, T. L., & Heuvelen, A. V. (2001). Surveyings tudents´ conceptual knowledge of electricity and magnetism. *American Journal of Physics*, *69*(7),12-23

Hlabane, A. S. (2016). An exploration into learning difficulties experienced by Physical Sciences learners in South African schools.

Hlalele, D. (2012). Exploring rural high school learners' experience of mathematics anxiety in academic settings. *South African Journal of Education*, *32*(3), 267-278.

Hodson, D. (1991). Practical work in science: Time for a reappraisal.

Hubber, P. (2018). Electricity. In K. Skamp & C. Preston (Eds.), *Teaching primary science constructively* (6th ed., pp. 194–224). Cengage Learning Australia.

Human Sciences Research Council, Nelson Mandela Foundation, Education Policy Consortium (South Africa)., & Education Policy Consortium (South Africa). (2005). *Emerging voices: A report on education in South African rural communities*. HSRC Press.

Irvine, A. (2011). Duration, dominance and depth in telephone and face-to-face interviews: A comparative exploration. *International Journal of Qualitative Methods, 10*(3), 202-220.

John, M. (2019). Physical sciences teaching and learning in Eastern Cape rural schools: Reflections of pre-service teachers. *South African Journal of Education*, *39*.

Johnson, B. & Christensen, L. (2008). *Focus groups: A practical guide for applied research.* London: SAGE Publications.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of computer assisted learning*, *7*(2), 75-83.

Jokiranta, K. (2014). The effectiveness of practical work in science education.

Jordan, M., & Adrienne, H. (2004). Fifty strategies for teaching English language learners. *California State University, Fesno: Person Longman*.

Karlsson, A., Nygård Larsson, P., & Jakobsson, A. (2020). The continuity of learning in a translanguaging science classroom. Cultural Studies of Science Education, 15(1), 1–25. https://doi. org/10.1007/s11422-019-09933-y

Kay, G. (2014). *Science practical work: what types of knowledge do secondary science teachers use?* (Unpublished Master's thesis, University of Cape Town).

Khisty, L. L. (1993). A naturalistic look at language factors in mathematics teaching in bilingual classrooms. In *Proceedings of the third national research symposium on limited English proficient student issues: Focus on middle and high school issues*. Washington, DC: UD Department of Education, Office of Bilingual and Minority Language Affairs.

Kibirige, I., & Maponya, D. (2021). Exploring Grade 11 Physical Science Teachers' Perceptions of Practical Work in Mankweng Circuit, South Africa. *Journal of Turkish Science Education*, *18*(1), 73-90.

Kibirige, I., & Maponya, D. (2021). Exploring Grade 11 physical science teachers' perceptions of practical work in Mankweng circuit, South Africa. *Journal of Turkish Science Education*, *18*(1), 73-90.

Kibirige, I., & Modjadji, S. E. (2022). Grade 10 Girls‘ Experiences in Choosing STEM Subjects in Rakwadu Circuit, South Africa. In *Advances in Research in STEM Education*. IntechOpen.

Kind, V. (2014). Science teachers‘ content knowledge. In H. Venkat, M. Rollnick, J. Loughran, & M. Askew (Eds.), *Exploring Mathematics and Science Teachers' Knowledge* (pp. 37-50). Routledge.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of higher education*, *6*(5), 26-41.

Köhler, T. (2022). Class size and learner outcomes in South African schools: The role of school socioeconomic status. *Development Southern Africa*, *39*(2), 126-150.

Kola, A. J. (2013). Importance of science education to national development and problems militating against its development. *American Journal of Educational Research*, *1*(7), 225-229.

Kola, A. J. (2017). Investigating the Conceptual Understanding of Physics through an Interactive Lecture-Engagement. *Cumhuriyet International Journal of Education*, *6*(1), 82.

Korganci, N., Miron, C., Dafinei, A., & Antohe, S. (2015). The importance of inquiry-based learning on electric circuit models for conceptual understanding. *Procedia-Social and Behavioral Sciences*, *191*, 2463-2468.

Koudelkova, V., & Dvorak, L. (2018). High school‘s students´ misconceptions about electricity and magnetism and how to diagnose them. *Paper presented at the International Conference on Physics Education* (pp. 898-905).

Küçüközer, H. & Demirci, N. (2005). High School Physics Teachers' Forms of Thought about Simple Electric Circuits. *23th International Physics Congress*, Muğla University 13-16 September.

Küçüközer, H., & Kocakülah, S. (2007). Secondary school students‘ misconceptions about simple electric circuits. Journal of Turkish Science Education, 4, 101–115.

Kuhn, T. S. (1970). Reflections on my critics.

Kuhn, T.S. (1970). *The Structure of Scientific Revolutions*, The University of Chicago Press. 2nd edn, International Encyclopedia of Unified Science, enlarged, first published 1962

Larson, R. K., & Street, D. L. (2013). IFRS teaching resources: Available and rapidly growing. In *Teaching ifrs* (pp. 19-40). Routledge.

Laurillard, D. (2002). Design tools for e-learning.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1*(3).

Lee, Y. & Law, N. (2001). Explorations in Promoting Conceptual Change in Electrical Concepts via Ontological Category Shift. *International Journal of Science Education, 23* (2), 111- 149.

Leedy, P. D., & Ormrod, J. E. (2015). Chapter 1 The nature and tools of research. *Practical research: Planning and design*, 19-26.

Legari, K. (2004). *Teaching Physical Science in rural (under-resourced) secondary schools*. (Unpublished master's research report, University of KwaZulu-Natal, Durban).

Lehesvuori, S., & Ametller, J. (2021). Exploring coherence and authorship in pedagogical link-making in science. *International Journal of Science Education*, *43*(17), 2791-2813.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Ablex Publishing Corporation, 355 Chestnut Street, Norwood, NJ 07648 (hardback: ISBN-0-89391-565-3; paperback: ISBN-0-89391-566-1).

Lemke, J. L. (1998). Multimedia literacy demands of the scientific curriculum. *Linguistics and Education*, *10*(3), 247-271.

Lemmer, M., Edwards, J. A., & Rapule, S. (2008). Educators' selection and evaluation of natural sciences textbooks. *South African Journal of Education*, *28*(2), 175-187.

Li, J. (2012). *Improving students' understanding of electricity and magnetism* (Doctoral dissertation, University of Pittsburgh).

Liepertz, S., & Borowski, A. (2018). Testing the consensus model: Relationships among physics teachers' professional knowledge, interconnectedness of content structure and student achievement. *International Journal of Science Education*. *41*(7), 71–92

Lodge, J. M., Kennedy, G., Lockyer, L., Arguel, A., & Pachman, M. (2018). Understanding difficulties and resulting confusion in learning: An integrative review. In *Frontiers in Education* (Vol. 3, p. 49). Frontiers Media SA.

Loughran, J., Berry, A., & Mulhall, P. (2012). *Understanding and Developing Science Teachers' Pedagogical Content Knowledge* (Vol. 12). Springer Science & Business Media.

Luft, J., Firestone, J. B., Wong, S. S., Ortega, I., Adams, K., & Bang, E. (2011). Beginning Secondary Science Teachers Induction: A Two-Year Mixed Methods Study. *Journal of Research in Science Teaching, 48*(10), 1199-1224.

Maclellan, E., & Soden, R. (2003). Expertise, expert teaching and experienced teachers'knowledge of learning theory. *Scottish Educational Review*, *35*(2), 110-120.

Magnusson, S., Krajcik, J. & Borko, H. 1999. Nature, sources, and development of pedagogical content knowledge for science teaching. (In Gess-Newsome, J. & Lederman, N.G., eds. Examining pedagogical content knowledge. Dordrecht: Springer. p. 95-132).

Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education*, *9*(3).

Makori, A., & Onderi, H. (2014). Examining the teaching and learning resources related challenges facing small and medium-sized public secondary schools in Kenya: A comparative analysis.

Manion, V., & Alexander, J. M. (1997). The benefits of peer collaboration on strategy use, metacognitive causal attribution, and recall. *Journal of Experimental Child Psychology*, *67*(2), 268-289.

Maringe, F., Masinire, A., & Nkambule, T. (2015). Distinctive features of schools in multiple deprived communities in South Africa: Implications for policy and leadership. *Educational Management Administration & Leadership*, *43*(3), 363-385.

Marzano, R. J. (2017). *The new art and science of teaching* (p. 110). Bloomington, IN: Solution Tree Press.

Masinire, A. (2015). Recruiting and retaining teachers in rural schools in South Africa: Insights from a rural teaching experience programme. *Australian and International Journal of Rural Education*, *25*(1), 2-14.

Masinire, A., Maringe, F., & Nkambule, T. (2014). Education for rural development: Embedding rural dimensions in initial teacher preparation. *Perspectives in Education*, *32*(3), 146-158.

Matthews, M. R. (1998). Introductory Comments on Philosophy and Constructivism in Science Education (pp. 1-10). In M. R. Matthews (Ed), *Constructivism in Science Education*. Dordretcht: Kluwer Academic Publishers.

Mavhunga, E., & Rollnick, M. (2013). Improving PCK of chemical equilibrium in pre-service teachers. African Journal of Research in Mathematics, Science and Technology Education, 17, 113–125.

Mavhunga, E., & van der Merwe, D. (2020). Bridging Science Education's Theory–Practice Divide: A Perspective from Teacher Education Through Topic-Specific PCK. *African journal of research in mathematics, science and technology education*, *24*(1), 65-80.

Mavhunga, M. E. (2012). *Explicit inclusion of topic specific knowledge for teaching and the development of PCK in pre-service science teachers.* University of the Witwatersrand, Johannesburg, South Africa. (unpublished doctoral dissertation)

Mavuru, L. & Ramnarain, U. (2017). Role of contextual knowledge in the pedagogical content knowledge of grade 9 natural sciences teachers in Johannesburg. *In Mhlolo,* *M.K., Matoti, S.N. & Fredericks, B., eds. Proceedings of the 25th Annual Meeting of SAARMSTE*, Central University of Technology. Bloemfontein: Sun Media. p. 233-244).

Mayer, R. E., & Massa, L. J. (2003). Three facets of visual and verbal learners: Cognitive ability, cognitive style, and learning preference. *Journal of educational psychology*, *95*(4), 833.

Mbonyiryivuze, A., Yadav, L. L., & Amadalo, M. M. (2019). Students‘ conceptual understanding of electricity and magnetism and its implications: A review. *African Journal of Educational Studies in Mathematics and Sciences*, *15*(2), 55-67.

McComas, W. F. (Ed.) (2014). The Language of Science Education: *An Expanded Glossary of Key Terms and Concepts in Science Teaching and Learning*. Rotterdam: Sense Publishers.

McMillan, J. H. (2012). *Educational Research: Fundamentals for the consumer*. (6th ed.). Cape Town: Pearson Education, Inc.

McMillan, J.H. & Schumacher, S. (2010). *Research in Education: Evidence-based inquiry*. (7th Ed.) Pearson Education, Inc. New Jersey: Upper Saddle River.

Meana, W. E. (2009). *Curriculum innovation in teacher education: Exploring conception among Tanzanian teacher educators*. University Press. Åbo Akademi: Åbo

Melo-Niño, L. V., Cañada, F., & Mellado, V. (2017). Initial characterization of Colombian high school physics teachers‘ pedagogical content knowledge on electric fields. *Research in Science Education*, *47*, 25-48.

Menoe, J. M. (2005). *Dealing with mixed abilities in standard grade Mathematics classes in South Africa* (Unpublished Master's thesis, University of Twente).

Métioui, A., & Trudel, L. (2012). Acquiring knowledge in learning concepts from electrical circuits: the use of multiple representations in technology-based learning environments. *Journal of Systemics, Cybernetics and Informatics, 10*(2), 24-35.

Mika, R.T. (2019). *Exploring an effect of an intervention on the integration of local knowledge in Grade 9 Physical Science lessons*. (unpublished Master‘s thesis, Rhodes University, South Africa).

Millar, R. (2004). The role of practical work in the teaching and learning of science. *Commissioned paper-Committee on High School Science Laboratories: Role and Vision. Washington DC: National Academy of Sciences, 308*.

Mji, A., & Makgato, M. (2006). Factors Associated with high school learners‘ performance: A spotlight on Mathematics and Physical Sciences. *South African Journal of Education*, 26 (2), 253 –266.

Mji, A., & Makgato, M. (2006). Factors Associated with high school learners‗ poor performance: A spotlight on Mathematics and Physical Sciences. South African Journal of Education, 26 (2), 253 –266.

Molapo, M.R. & Pillay, V. (2018). Politicising curriculum implementation: the case of primary schools. *South African journal of education, 38*(1):1-9.

Moletsane, R. (2012). Repositioning educational research on rurality and rural education in South Africa: Beyond deficit paradigms. *Perspectives in Education*, *30*(1), 1.

Moodley, G. (2013). Implementation of the Curriculum and Assessment Policy Statements: challenges and implications for the teaching and learning. Pretoria: UNISA. (unpublished Dissertation-MEd).

Moodley, K., & Gaigher, E. (2015). TEACHING ELECTRIC CIRCUITS: TEACHERS'IDEAS AND UNDERSTANDING OF MISCONCEPTIONS.

Moodley, K., & Gaigher, E. (2019). Teaching electric circuits: Teachers‗ perceptions and learners‗ misconceptions. *Research in Science Education*, *49*, 73-89.

Morgan, D. L. (2007). Paradigms lost and pragmatism regained methodological implications of combining qualitative and quantitative methods. *Journal of mixed methods research, 1*(1), 48-76.

Mortimer, E.F., & Scott, P.H. (2003). *Meaning-making in secondary science classrooms*. Buckingham, UK: Open University Press

Msila, V. (2007). From apartheid education to the revised national curriculum statement: Pedagogy for identity formation and nation building in South Africa. Nordic Journal of African Studies, 16(2), 146-160.

Mthethwa-Kunene, E., Onwu, G. O. & de Villiers, R. (2015). Exploring Biology Teachers‗ Pedagogical Content Knowledge in the Teaching of Genetics in Swaziland Science Classrooms. *International Journal of Science Education, 37*(7), 1140-1165.

Mtsi, N., & Maphosa, C. (2016). Challenges Encountered in the Teaching and Learning of the Natural Sciences in Rural Schools in South Africa. *Journal of Social Sciences*, *47*(1), 58-67.

Mudaly, V., & Mpofu, S. (2019). Learners‗ views on asymptotes of a hyperbola and exponential function: A commognitive approach. *Problems of Education in the 21st Century*, *77*(6), 734.

Mudau, A. V., & Tabane, R. (2014). Practical Work as It Says Practical is Something Students do by Themselves…. *Mediterranean Journal of Social Sciences, 5*(3), 446.

Mutende, R. A., Akala, W., & Imonje, R. K. (2021). Connecting Theory and Practice: Pre-service Science Teachers' Adoption and Implementation of the Demonstration

Method. *International Journal of Learning, Teaching and Educational Research*, *20*(5), 189-210.

Muwanga-Zake, J. W. (2001). Is science education in a crisis? Some of the problems in South Africa. *Science in Africa*, *2*, 1-14.

Muwanga-Zake, J. W. F. (1998). *Research portfolio*. (Unpublished master's research report, Rhodes University, South Africa)

Mweli, H.M. (2017). Inclusive Education and Special Education: DBE Progress Report; with Deputy Minister (Parliament Report) Available from: https://pmg.org.za/files/170530ProgressREPORT.pptx

Namugaya, J., & Habumugisha, I. (2017, February). Current Causes of Girls' Low Performance in Physical Sciences from Hard-to-reach Secondary Schools in Eastern Uganda. *International Journal of Secondary Education*. Vol.5, No. 1, 2017, pp. 12-15. doi: 10.11648/j.ijsedu.20170501.12.

Nappi, J. S. (2017). The importance of questioning in developing critical thinking skills. *Delta Kappa Gamma Bulletin*, *84*(1), 30.

Narjaikaew, P., Emarat, N., Arayathanitkul, K., & Cowie, B. (2010). Magnetism teaching sequences based on an inductive approach for first-year Thai university science students. *International Journal of Science and Mathematics Education*, *8*(5), 891-910.

Ncube, M. (2014). *Investigating the learners' interpretation of everyday words when used in the physics context in South African classrooms*. (Unpublished master's research report, University of the Witwatersrand, South Africa).

Ndlovu, B.P. (2017). Examining the development of topic specific pedagogical content knowledge in stoichiometry in pre-service teachers. Johannesburg: University of the Witwatersrand. (unpublished Masters Dissertation).

Needham, R. (2014). The contribution of practical work to the science curriculum. *School Science Review*, *95*(352), 63-69.

Ng, C. & Leicht, A. (2019). 'Struggles as Engagement' in teacher change: a longitudinal case study of a reading teacher's changing practices. *Teachers and teaching: theory and practice*, *25*(4):453- 468.

Nguyen, N. T., McFadden, A., Tangen, D. J., & Beutel, D. A. (2013). *Video-stimulated recall interviews in qualitative research*.

Njie, B., & Asimiran, S. (2014). Case study as a choice in qualitative methodology. *IOSR Journal of Research and Method in Education*, *4*(3), 35-40.

Nkambule, T. (2022). Exploring working conditions in selected rural schools: teachers' experiences. *South African Journal of Education*, *42*(1).

Nkambule, T. C. (2017). Student teachers‘ perceptions of a Wits rural teaching experience project: What to learn and improve. *South African Journal of Higher Education*, *31*(1), 191-206.

Nkambule, T., & Mukeredzi, T. G. (2017). Pre-service teachers' professional learning experiences during rural teaching practice in Acornhoek, Mpumalanga Province. *South African Journal of Education*, *37*(3), 1-9.

Nkambule, T., Balfour, R. J., Pillay, G., & Moletsane, R. (2011). Rurality and rural education: Discourses underpinning rurality and rural education research in South African postgraduate education research 1994-2004. *South African Journal of Higher Education*, *25*(2), 341-357.

Noguera J.S. (2018). The Role of Classroom Observation in Pre-Service English Teachers‘ Understanding of the Teaching Profession. Porta Linguarum.

Nzoka, J. T., & Orodho, J. A. (2014). School management and students‘ academic performance: How effective are strategies being employed by school managers in secondary schools in Embu North District, Embu County, Kenya. *International Journal of Humanities and social science*, *4*(9), 86-99.

Ogegbo, A. A., Gaigher, E., & Salagaram, T. (2019). Benefits and challenges of lesson study: A case of teaching Physical Sciences in South Africa. *South African Journal of Education*, *39*(1).

Ogunniyi, M. B., & Rollnick, M. (2015). Pre-service science teacher education in Africa: Prospects and challenges. *Journal of Science Teacher Education*, *26*(1), 65-79.

Oh, P. S. & Kim, K. S. (2013). Pedagogical Transformations of Science Content Knowledge in Korean Elementary Classrooms, *International Journal of Science Education, 35*(9), 1590-1624

Okam, C. C., & Zakari, I. I. (2017). ― Impact of Laboratory-Based Teaching Strategy on Students ‘ Attitudes and Mastery of Chemistry in Katsina Metropolis ‖, Katsina State , Nigeria. *International Journal of Innovative Research and Development, 6*(1), 112–121.

Okesina, M. (2020). A critical review of the relationship between paradigm, methodology, design and method in research. *Journal of Research & Method in Education*, *10*(3), 57-68.

Onder, F., Senyigit, C., & Silay, I. (2017). The effects of misconception on pre-service teachers‘ ability to constructing simple electric circuits. *European Journal of Physics Education, 8*(1), 1–10.

Oyoo, S. O. (2012). Language in science classrooms: an analysis of physics teachers‘ use of and beliefs about language. *Research in Science Education*, *42*(5), 849-873.

Oyoo, S. O. (2017). Learner Outcomes in Science in South Africa: Role of the Nature of Learner Difficulties with the Language for Learning and Teaching Science. *Research in Science Education.* pp. 1-22. DOI 10.1007/s11165-016-9528-8.

Pacana, N. M. S., Ramos, C. D., Catarata, M. N., & Inocian, R. B. (2019). Out-of-Field Social Studies Teaching through Sustainable Culture-Based Pedagogy: A Filipino Perspective. *International Journal of Education and Practice*, *7*(3), 230-241.

Park, S., & Chen, Y. C. (2012). Mapping out the integration of the components of pedagogical content knowledge (PCK): Examples from high school biology classrooms. *Journal of Research in Science Teaching*, *49*(7), 922-941.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education*,*38*(3), 261-284.

Paskins, Z., Sanders, T., Croft, P. R., & Hassell, A. B. (2017). Exploring the added value of video-stimulated recall in researching the primary care doctor–patient consultation: a process evaluation. *International Journal of Qualitative Methods*, *16*(1), 1609406917719623.

Patton, M. Q., & Cochran, M. (2002). A guide to using qualitative research methodology. *Medecins Sans Frontiers. Retrieved February*, *14*, 2017.

Paxton, C. (2015). *Possibilities and constraints for improvement in rural South African schools*. (unpublished PhD Thesis).

Penuel, W. R., Gallagher, L. P., & Moorthy, S. (2011). Preparing Teachers to Design Sequences of Instruction in Earth Systems Science A Comparison of Three Professional Development Programs. *American Educational Research Journal*, *48*(4), 996-1025.

Permatasari, M. B., Rahayu, S., & Dasna, I. W. (2022). Chemistry Learning Using Multiple Representations: A Systematic Literature Review. *Journal of Science Learning*, *5*(2), 334-341.

Petrus, R. M. (2018). A Comparison of Teachers' and Students' Perceptions of the Factors Contributing to Poor Performance in Physical Sciences: A Case of South Africa. *Journal of Turkish Science Education*, *15*(4), 93-103.

Planinic, M., Milin-Sipus, Z., Katic, H., Susac, A., & Ivanjek, L. (2012). Comparison of student understanding of line graph slope in physics and Mathematics. *International journal of science and Mathematics education*, *10*(6), 1393-1414.

Ponelis, S. R. (2015). Using interpretive qualitative case studies for exploratory research in doctoral studies: A case of Information Systems research in small and medium enterprises. *International Journal of Doctoral Studies*, *10*(1), 535-550.

Poni, M. (2014). Research paradigms in education. *Journal of Educational and Social Research*, *4*(1), 407.

Pozzebon, M. (2004). Conducting and evaluating critical interpretive research: Examining criteria as a key component in building a research tradition. In *Information Systems Research* (pp. 275-292). Springer US.

Prain, V., & Tytler, R. (2012). Learning through constructing representations in science: A framework of representational construction affordances. *International Journal of Science Education, 34*(17), 2751-2773.

Preston, C. (2017). Effect of a diagram on primary students understanding about electric circuits. *Research in Science Education, 49*(5), 1433–1456.

Preston, C. M. (2019). Effect of a diagram on primary students' understanding about electric circuits. *Research in Science Education, 49*, 1433-1456.

Preston, C. M., Hubber, P. J., & Xu, L. (2022). Teaching About Electricity in Primary School Multimodality and Variation Theory as Analytical Lenses. *Research in Science Education*, *52*(3), 949-973.

Price, A. (2017). An overview of the phenomenon of teaching out of field. *Unterrichtswissenschaft*, *45*(2), 102-113.

Putri, L. P., Russell, D. J., O'Sullivan, B. G., Meliala, A., & Kippen, R. (2022). A critical review of definitions of rural areas in Indonesia and implications for health workforce policy and research. *Health Research Policy and Systems*, *20*(1), 1-15.

Qian, Y., Hambrusch, S., Yadav, A., Gretter, S., & Li, Y. (2020). Teachers' perceptions of student misconceptions in introductory programming. *Journal of Educational Computing Research*, *58*(2), 364-397.

Rajagopalan, I. (2019). Concept of Teaching. *Shanlax International Journal of Education, 7*(2), 5-8.

Ramdas, B., & Yashoda, G. (2020). A Study on the Learning Difficulties in Physical Science at Secondary School Level. *Available at SSRN 3701442*.

Ramma, Y., Bholoa, A., Watts, M., & Ramasawmy, J. (2014). Pre-and in-service physics teachers' content and pedagogical content knowledge: Implications and challenges. *American International Journal of Research in Science, Technology, Engineering & Mathematics, 1*(8), 30–34.

Ramnarain, U. & Hlatswayo, M. (2018). Teacher beliefs and attitudes about inquiry-based learning in a rural school district in South Africa. *South African journal of education, 38*(1):1-10.

Ramnarain, U. D. (2014). Teachers' perceptions of inquiry-based learning in urban, suburban, township and rural high schools: The context-specificity of science curriculum implementation in South Africa. *Teaching and teacher education*, *38*, 65-75.

Rea-Dickins, P. (2004). Understanding teachers as agents of assessment. *Language Testing, 21*(3), 249-258.

Reddy, M., & Panacharoensawad, B. (2017). Students Problem-Solving Difficulties and Implications in Physics: An Empirical Study on Influencing Factors. *Journal of Education and Practice, 8*(14), 59-62.

Rehman, A. A., & Alharthi, K. (2016). An introduction to research paradigms. *International Journal of Educational Investigations, 3*(8), 51-59.

Rice, J. K. (2010). The Impact of Teacher Experience: Examining the Evidence and Policy Implications. Brief No. 11. *National center for analysis of longitudinal data in education research*.

Ritchie, J., Lewis, J., Nicholls, C. M., & Ormston, R. (Eds.). (2013). *Qualitative research practice: A guide for social science students and researchers*. sage.

Rogan, J. M. (2007). How much curriculum change is appropriate? Defining a zone of feasible innovation. *Science Education, 91*(3), 439-460.

Rollnick, M., & Mavhunga, E. (2014). PCK of teaching electrochemistry in chemistry teachers: A case in Johannesburg, Gauteng Province, South Africa. *Educación química, 25*(3), 354-362.

Rollnick, M., & Mavhunga, E. (2015). PCK Summit and its effect on work in South Africa. In A. Berry, P. Friedrichsen, & J. Loughran, Re-examining Pedagogical Content Knowledge in Science Education (pp. 135-146). New York: Routledge.

Roth, W.-M. (2014). Science language wanted alive: through the dialectical/dialogical lens of Vygotsky and Bakhtin Circle. *Journal of Research in Science Teaching, 51*(8), 1049–1083.

Roy, S., & Bairagya, S. (2019). Conceptualisation of Pedagogical Content Knowledge (PCK) of science from Shulman‘s notion to Refined Consensus Model (RCM): A journey. *Refer. J. Dial. Educ, 8*(2), 10-53.

Rustandi, A & Mubarok A Husni. (2017). An analysis of IRF (Initiation-ResponseFeedback) on classroom interaction in EFL speaking class. *EduLite, 2*(1), 239– 250.

Rusznyak, L. & Walton, E. (2011). Lesson planning guidelines for student teachers: A scaffold for the development of pedagogical content knowledge. *Education as Change, 15*(2), 271-285.

Rusznyak, L., Hlatshwayo, M. N., Fataar, A., & Blackie, M. (2021). Knowledge-building and knowers in educational practices. *Journal of Education (University of KwaZulu-Natal)*, (83), 1-12.

Saglam, M., & Millar, R. (2006). Upper high school students‘ understanding of Electromagnetism. *International Journal of Science Education, 28*(5), 543-566.

Schlotterbeck, D., Araya, R., Caballero, D., Jimenez, A., Lehesvuori, S., & Viiri, J. (2020). Assessing teacher‘s discourse effect on students‘ learning: A keyword centrality approach. In *Addressing Global Challenges and Quality Education: 15th European Conference on Technology Enhanced Learning, EC-TEL 2020, Heidelberg, Germany, September 14–18, 2020, Proceedings 15* (pp. 102-116). Springer International Publishing.

Scott, P., Asoko, H., & Leach, J. (2013). Student conceptions and conceptual learning in science. In *Handbook of research on science education* (pp. 45-70). Routledge.

Scott, P., Mortimer, E., & Ametller, J. (2011). Pedagogical link-making: a fundamental aspect of teaching and learning scientific conceptual knowledge. *Studies in Science Education*, *47*(1), 3-36.

Sebatana, M. J., & Dudu, W. T. (2022). Reality or Mirage: Enhancing 21st-Century Skills Through Problem-Based Learning While Teaching Particulate Nature of Matter. *International Journal of Science and Mathematics Education*, *20*(5), 963-980.

Sequeira, A. H. (2012). Introduction to concepts of teaching and learning. *Social sciences education e-journal*.

Shah, R. K., & Campus, S. (2021). Conceptualizing and defining pedagogy. *IOSR Journal of Research & Method in Education*, *11*(1), 6-29.

Shah, S. R., & Al-Bargi, A. (2013). Research Paradigms: Researchers' Worldviews, Theoretical Frameworks and Study Designs. *Arab World English Journal*, *4*(4).

Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on high students' academic achievement. *JOTSE*, *10*(2), 199-215.

Shanmugavelu, G., Ariffin, K., Vadivelu, M., Mahayudin, Z., & Sundaram, M. A. R. (2020). Questioning Techniques and Teachers' Role in the Classroom. *Shanlax International Journal of Education*, *8*(4), 45-49.

Sherin, B. L. (2001). How students understand physics equations. *Cognition and instruction*, *19*(4), 479-541.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57, 1–21.

Simons, H. (2009). *Case study research in practice*. SAGE publications.

Soliman, D., Frydenberg, E., Liang, R., and Deans, J. (2021). Enhancing empathy in preschoolers: a comparison of social and emotional learning approaches. *Educ. Dev. Psychol.* 38, 64–76. doi: 10.1080/20590776.2020.1839883

Sotiriou, S., Bybee, R., & Bogner, F. (2017). PATHWAYS –A Case of Large-Scale Implementation of Evidence-Based Practice in Scientific Inquiry-Based Science Education. *International Journal of Higher Education*, *6*(3), 8. https://doi.org/10.5430/ijhe.v6n2p8

Spaull, N. (2013). South Africa's education crisis: The quality of education in South Africa 1994-2011. *Johannesburg: Centre for Development and Enterprise*.

Staarman, J. K., & Ametller, J. (2019). Pedagogical link-making with digital technology in science classrooms: New perspectives on connected learning. In *The Routledge international handbook of research on dialogic education* (pp. 497-508). Routledge.

Stake, R. E. (1995). *The art of case study research*. Sage.

Stake, R. E. (2005). Qualitative case studies.

Statistics South Africa. (2003). *Census 2001: How the count was done* (No. 3). Statistics South Africa.

Stender, A., Brückmann, M., & Neumann, K. (2017). Transformation of topic-specific professional knowledge into personal pedagogical content knowledge through lesson planning. *International Journal of Science Education*, *39*(12), 1690-1714.

Stephen, M.M. (2018). *The Role of Physical Science Subject Advisors In Enhancing The Quality Of The Teaching Of Physical Science In The FET Phase (Grade 10-12).* Unpublished doctoral thesis, University Of South Africa, South Africa.

Sumranwanich, W., & Yuenyong, C. (2014). Graduate students' concepts of nature of science (NOS) and attitudes toward teaching NOS. *Procedia-Social and Behavioral Sciences*, *116*, 2443-2452.

Thanh, N. C., & Thanh, T. T. (2015). The interconnection between interpretivist paradigm and qualitative methods in Education. *American Journal of Educational Science*, *1*(2), 24-27.

Tiberghien, A., Malkoun, L., Buty, C., Soussy, N. & Mortimer, E.F. (2007). Analysis of knowledge at stake in physics classrooms across different time scales. In *The joint action of teaching teachers and students*, Eds. Sensevy, G. & Mercier, A. 73–98. Rennes, France: Presses Universitaires de Rennes.

Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School science and Mathematics*, *90*(5), 403-418.

Tofade, T., Elsner, J., & Haines, S. T. (2013). Best practice strategies for effective use of questions as a teaching tool. *American journal of pharmaceutical education*, *77*(7).

Trengove, E. (2012). *Lightning myths and beliefs in South Africa: their effect on personal safety* (Doctoral dissertation, University of the Witwatersrand, Faculty of Engineering and the Built Environment, School of Electrical and Information Engineering).

Tsakeni, M. (2017). Science teaching orientations for CAPS Physical Sciences practical work: a case study. In *The Proceedings: towards effective teaching and meaningful learning in mathematics, science and technology education. UNISA/ISTE Conference on Mathematics, Science and Technology Education*, Mopani Camp, Kruger National Park: UNISA. p. 323-330.

Tsakeni, M. (2018). Opportunities for teaching sustainable development through the chemistry component of CAPS physical sciences. *African journal of research in mathematics, science and technology education, 22*(1):125-136.

Urban-Woldron, H. (2014). Testing student conceptual understanding of electric circuits as a system. *In E-Book Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning*, 11, 38 -50.

Usak, M., Ozden, M., and Eilks, I. (2011). A case study of beginning science teachers‘ subject matter (SMK) and pedagogical content knowledge (PCK) of teaching chemical reaction in Turkey. *European Journal of Teacher Education, 34*(4), 407-429.

Uzuntiryaki, E., & Geban, Ö. (2005). Effect of conceptual change approach accompanied with concept mapping on understanding of solution concepts. *Instructional science*, *33*, 311-339.

Van der Merwe, O. R., & Gaigher, E. (2011). Teachers‘ awareness of learners‘ misconceptions about simple circuits.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press, Cambridge, MA: London.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge, MA: MIT Press.

Wandberg, R., & Rohwer, J. (2009). *Teaching health education in language diverse classrooms*. Jones & Bartlett Learning.

Weisman, D. L. (2012). An essay on the art and science of teaching. *The American Economist*, *57*(1), 111-125.

White, C. J., & Van Dyk, H. (2019). Theory and practice of the quintile ranking of schools in South Africa: A financial management perspective. *South African Journal of Education*, *39*(Supplement 1), s1-19.

World Bank (2014). Rural Population.

Available: http://data.worldbank.org/indicator/SP.RUR.TOTL [August 7, 2015].

Yin, R. K. (2013). *Case study research: Design and methods*: Sage publications.

Yin, R. K. (2018). *Case study research and applications: design and methods*. Sixth edition. Los Angeles, SAGE.

Zhou, S., Wang, Y., & Zhang, C. (2016). Pre-Service Science Teachers' PCK: Inconsistency of Pre-Service Teachers' Predictions and Student Learning Difficulties in Newton's Third Law. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(3).

Zohud, N. W. I. (2015). Teaching strategies and their role on students‘ engagement in learning English. *An-Najah National University*.

Zulu, S.I. (2018). *Exploring Grade 10 rural Physical Science teachers‘ perceptions and usage of everyday words in Acornhoek science classrooms, Mpumalanga Province.* (Unpublished masters dissertation, University of the Witwatersrand, Johannesburg, South Africa).

Zydney JM, Hasselbring TS. (2014). Mini anchors: A universal design for learning approach. *TechTrends 58*:21–28.

APPENDICES

Appendix 1: Wits Ethical Clearance

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Zulu

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H19/03/35**
PROJECT TITLE	Exploring the teaching and learning of Grade 10 electricity and magnetism in Vryheid rural schools, KwaZulu-Natal Province
INVESTIGATOR(S)	Mr S Zulu
SCHOOL/DEPARTMENT	Education/
DATE CONSIDERED	15 March 2019
DECISION OF THE COMMITTEE	Approved Permission letters from Schools are needed before data collection can commence
EXPIRY DATE	11 June 2022

DATE 12 June 2019 **CHAIRPERSON** J Knight
(Professor J Knight)

cc: Supervisor : Dr T Nkambule and Dr E Mushayikwa

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

____
Signature

_____/_____/_____
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix 2: KwaZulu-Natal Department of Basic Education

education

Department:
Education
PROVINCE OF KWAZULU-NATAL

Enquiries: Phindile Duma | Tel: 033 392 1063 | Ref.:2/4/8/1772

Mr SI Zulu
PO Box 88
Hlobane
3145

Dear Mr Zulu

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"EXPLORING GRADE 10 TEACHING AND LEARNING OF ELECTRICITY AND MAGNETISM IN VRYHEID RURAL SCHOOLS, KWAZULU-NATAL PROVINCE"**, in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 22 April 2019 to 01 September 2021.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers below.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

Zululand District

Dr. EV Nzama
Head of Department: Education
Date: 24 April 2019

Championing Quality Education - Creating and Securing a Brighter Future

KWAZULU-NATAL DEPARTMENT OF EDUCATION
Postal Address: Private Bag X9137 - Pietermaritzburg - 3200 - Republic of South Africa
Physical Address: 247 Burger Street - Anton Lembede Building - Pietermaritzburg - 3201
Tel.: +27 33 392 1063 - Fax.: +27 033 392 1203- Email: Phindile.Duma@kzndoe.gov.za -Web: www.kzneducation.gov.za
Facebook: KZNDOE....Twitter: @DBE_KZN....Instagram: kzn_education....Youtube:kzndoe

Appendix 3: INFORMATION SHEET FOR LEARNERS

DATE:

Dear Learner

My name is Sphamandla Zulu and I am a PhD student in the School of Education at the University of the Witwatersrand. I am doing research on ―**Exploring the teaching and learning of Grade 10 Electricity and Magnetism in Vryheid rural schools, KwaZulu-Natal Province**‖.

My investigation involves observing your physical science lessons on the topic of Electricity and Magnetism. The lessons will be video recorded, with the focus on the classroom activities, and then video recorded lessons will be analyzed for the purpose of this research study. As a Grade 10 learner, you will not be required to do anything rather than being present for your physical science lessons as you normally do. The video recorder will be positioned at the back of your classroom and it is used to help me with data that I can observe several times in order to facilitate an in-depth analysis of the lesson observations.

I am asking for your permission to come and sit in your physical science classroom to observe the teaching and learning of Electricity and Magnetism topic. I will not actively participate in the lessons and these lesson observations will take place during your normal physical science periods. I need your help with your participation during the lesson observations and video recording of the lessons, by being present in the lessons and allowing me to observe your lessons. Remember, this is not a test, it is not for marks and it is voluntary, which means that you don‗t have to do it and you may choose not to be video recorded. I will also like to interview three learners in your classroom to understand how best physical science teachers should teach the topic of Electricity and Magnetism. If it happens that you form part of these three learners (to be chosen after the teaching), I request for your voluntary participation in the interview. Also, if you decide halfway through that you prefer to stop with your participation, this is completely your choice and will not affect you negatively in any way.

I will not be using the video recorded lessons anywhere else except for the purpose of this study, so if you appear in the recorded video, your identity will be protected as your own name will not be used, and your face will be hidden to protect your identity. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely at Wits School of Education and be destroyed between 3-5 years after I have completed this project.

Your parents have also been given an information sheet and consent form, but at the end of the day it is your decision to join us in this study.

I look forward to working with you. If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email Shaun.Schoeman@wits.ac.za

Yours Sincerely,

Sphamandla Zulu	***Thabisile Nkambule***
spha.i.zulu@gmail.com	*Thabisile.Nkambule@wits.ac.za*
Tel: 0117173496	*Tel: 0117173049*
Cel: 0785493480	*Cel: 0734935098*
*[**Researcher**]*	*[**Research supervisor**]*

INCWADI YOLWAZI YOMFUNDI

USUKU: 01 Nhlaba 2019

Siyakubingelela mfundi

Igama lami ngingu Sphamandla Zulu ngenza iziqu zobudokotela kumkhakha wezemfundo (phecelezi PhD in education) esikoleni sokuqeqesha othisha enyuvesi yase Witwatersrand. Ngenza ucwaningo ngokufundiswa nangokufundwa kwe-Physical Science ezikoleni ezisemaphandleni. Lolucwaningo lusihloko sithi: **―Exploring Grade 10 rural teachers' and learners' teaching and learning of Electricity and Magnetism in Vryheid schools, KwaZulu-Natal Province‖**.

Lolucwaningo lami lubandakanya ukubukela ufundiswa nokufundwa kwesihloko i-Electricity kanye ne Magnetism esifundweni se-physical science. Izifundo ezibukeliwe zizoqoshwa phansi ngenhloso yokubhekelela nokucwaninga okwenzeka egumbini lukufundela i-electricity kanye ne magnetism. Njengomfundi webanga leshumi, uzobe ungalindelekile ukuba wenze okweqile kunalokho ohlale ukwenza, njengokuthi ubekhona egumbini lakho lokufundela. Njengomcwaningi ngizoma emuva egumbini lakho lokufundela ukuze ngingaphazamisi ukufunda nokufundiswa kwakho. Ukuzibandakanya kwakho kulolucwaningo ngeke kukuphe noma kukuncishe amamaki ezifundweni zakho.

Ngicela ukuba ungiphe imvume yokuza egumbini lakho lakufundela i-physical science ukuze ngibhekisise ukufundwa nokufundiswa kwesihloko se-―Electricity and Magnetism‖. Nginxusa ukuba uhlanganyele kulolucwaningo lami ngokuthi ubekhona egumbini lakho lokufundela i-physical science uma ngibhekisisa futhi ngithwebula (video record) ukufundwa nokufundiswa kwe Electricity kanye ne Magnetism. Ngicela ukuba ungiphe imvume yokuthi ngithwebule ukufundiswa nokufunda kwe Electricity kanye ne Magnetism ngesikhathi esijwayelekile sokufundwa kwalesisihloko. Khumbula, lolucwaningo akusikho ukuhlolwa kwakho, ngakho-ke ngeke uthole amamaki ngokuhlanganyela kulolucwaningo futhi uyobe uzibandakanya ngokuzithandela. Okusho ukuthi uma ungafisi ukuhlanganyela kulolucwaningo ungasho futhi ngeke ngikuthwebule egumbini lokufundela i-physical science. Ngifisa ukuxoxa nabafundi abathathu egumbini lakho lokufundela, ukuze ngiqondisise ukuba sifundiswa kanjani futhi sifundwa kanjani isihloko se Electricity ne Magnetism ngoba abafundi banenkinga ngaso kwibanga le shumi nambili? Uma kwenzeka ukuba usohlweni lwabafundi abathathu, ngicela ukuhlanganyela kwakho ngokuzithandela, futhi ungiphe imvume yokuba ngixoxe nawe. Okubalulekile, uma kwenzeka maphakathi ukuba awusafisi ukubandakanyeka kulolucwaningo, lokhu kuyisinqumo sakho, uvumelekile ukuba wenze kanjalo futhi uma wenze njalo ngeke ucikelelwe phansi noma uphathwe kabi nanoma ngayiphi indlela.

Angeke ngisebenzise ulwazi oluvela kumfanekiso othwetshuliwe nanoma yikuphi, ngaphandle kokusetshenziselwa kwenjongo yalolucwaningo. Ngakho-ke, uma uvela kulomfanekiso othwetshuliwe ngeke ubonakale ukuba ungubani futhi negama lakho ngekelisetshenziswe, kanye nobuso bakho buyofihlwa ukuze kungabonakali ukuba ungubani. Lonke ulwazi ngawe luzogcinwa luphephile futhi luyimfihlo kuwo wonke umbhalo ngalolucwaningo. Kanti okunye, lonke ulwazi oluqoqwe kulolucwaningo luzogcinwa endaweni ephephile kakhulu esikoleni sokuqeqesha othisha enyuvesi yase Witwatersrand, bese luyabhubhiswa eminyakeni emihlanu emva kokuphothulwa kwalolucwaningo. Nomzali wakho unikeziwe lencwadi yesicelo ukuba agunyaze ukubandakanyeka noma ukungabandakanyeki kwakho kulolucwaningo, kodwa-ke kuyisinqumo sakho ukufisa noma ukungafisi ukubandakanyeka kulolucwaningo.

Ngiyojabula kakhulu ukusebenzisana nawe kulolucwaningo. Uma kukhona ofuna ukukwazi mayelana nalolucwaningo noma ukubandakanyeka kwakho, ungaxhumana nami noma abaqondisi balolucwaningo kulemininingwane eshicilelwe ngezansi. Lolucwaningo luzobhalwa lube umbiko futhi luzobakhona kumtapo wolwazi wasenyuvesi yase Witwatersrand. Uma ufisa ukuthola isifinyezo salombiko, ngiyojabula kakhulu ukukuthumelela wona. Uma unokukhathazeka noma unezikhalazo eziphathelene nokuziphatha kwalolucwaningo, wamukelekile ukuxhumana ne - University Human Research Ethics Committee (Non-Medical), ocingweni oluthi +27(0) 11 717 1408, imeyili Shaun.Schoeman@wits.ac.za

Abazithobayo,

<table>
<tr><td>Sphamandla Zulu
spha.i.zulu@gmail.com
Tel: 0117173496
Cel: 0785493480
[Umcwaningi]</td><td>Thabisile Nkambule
Thabisile.Nkambule@wits.ac.za
Tel: 0117173049
Cel: 0734935098
[Umqondisi wocwaningo]</td></tr>
</table>

LEARNER ASSENT FORM

Please fill in the reply slip below if you agree to participate in my study called: **"Exploring the teaching and learning of Grade 10 Electricity and Magnetism in Vryheid rural schools, KwaZulu-Natal Province"**

My name is: _________________________and I agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. Please circle the relevant options below:

Permission to observe you in class	**Circle one**
I agree to be observed in class.	YES/NO
Permission to be videotaped	
I agree to be videotaped in class.	YES/NO
I know that the videotapes will be used for this project only.	YES/NO
Permission to be interviewed	
I would like to be interviewed for this study.	YES/NO
I know that I can stop the interview at any time and don't have to answer all the questions asked.	YES/NO
Permission to be audiotaped	
I agree to be audiotaped during the interview	YES/NO
I know that the audiotapes will be used for this project only	YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotaped
- All the data collected during this study will be destroyed within 3-5 years after completion of this project.

Sign________________________________ Date______________________________

IFOMU LOKUVUMELANA NOMFUNDI

Ngicela ukuba uphendule loluhla lwemibuzo elandelayo uma uvuma ukubamba iqhaza kulolucwaningo olusihloko sithi: **―Exploring Grade 10 rural teachers' and learners' teaching and learning of Electricity and Magnetism in Vryheid schools, KwaZulu-Natal Province‖**

Igama lami ngingu: ________________________futhi ngiyavuma ukubamba iqhaza kulolucwaningo. Lolucwaningo luchaziwe kabanzi kimi, futhi ngiyaqonda ukuthi ukubamba kwami iqhaza kulolucwaningo kubandakanya ini.

Ngicela ukuba usekele ukhetho olufanele kuloluhla olulandelayo:

Imvume yokukubhekelela egumbini lakho lokufundela	**sekela okukodwa**
Ngiyavuma ukuba ngibhekelelwe egumbini lami lokufundela.	YEBO/CHA

Imvume yokuthwetshulwa

Ngiyavuma ukuba ngithwetshulwe egumbini lokufundela.	YEBO/CHA
Ngiyazi ukuthi umfanekiso othwetshuliwe uzosetshenziselwa lolucwaningo kuphela.	YEBO/CHA

Imvume yenxoxo nothile

Ngingaxoxa nomcwaningi ngololucwaningo.	YEBO/CHA
Ngiyazi ukuba ngingayimisa inxoxo nothile nomcwaningi nanoma ngabe yisiphi isikhathi socwaningo futhi angiphoqelekile ukuba ngiphendule yonke imibuzo ebuzwa kwinxoxo nothile.	YEBO/CHA

Imvume yokuqoshwa kwenxoxo nothile

Ngiyavuma ukuba ngiqoshwe ngesikhathi senxoxo nothile	YEBO/CHA
Ngiyazi ukuthi ukuqoshwa kwenxoxo nothile yami nomcwaningi kuyosetshenziselwa lolucwaningo kuphela	YEBO/CHA

Imvume yokwaziswa

Ngiyaqonda ukuthi:

- Igama lami kanye nemininingwane yami izogcinwa endaweni eyimfihlo futhi ephephile. Kanti futhi igama lami kanye nelesikole sami angeke aziswe emphakathini kodwa umcwaningi kanye nalolucwaningo luzosebenzisa amagama mbumbulu ukukhuluma ngathi.
- Angiphoqelekile ukuba ngiphendule yonke imibuzo kulolucwaningo, futhi nginga hoxisa iqhaza lami kulolucwaningo.
- Ngingacela ukuba ngingathwetshulwa noma ingaqoshwa inxoxo yami nomcwaningi
- Lonke uhla lwemininingwane yalolucwaningo luzobhubhiswa esikhathini esiyiminyaka emihlanu emva kokuphothulwa kwalolucwaningo.

Isignesha ______________________________ Usuku____________________________

Appendix 4: INFORMATION SHEET FOR PARENTS

DATE:

Dear Parent

My name is Sphamandla Zulu and I am a PhD student in the School of Education at the University of the Witwatersrand. I am doing research on **―Exploring the teaching and learning of Grade 10 Electricity and Magnetism in Vryheid rural schools, KwaZulu-Natal Province‖**.

My research involves observing Grade 10 physical science lessons in the topic of Electricity and Magnetism to find out how science teachers teach the topic and how learners learn the topic. In so doing, this study will reveal teachers' pedagogic practices and learner's learning approaches to the topic, with considerations of other factors that may enhance or hinder the effective teaching and learning of the topic. I will video record all the observed Grade 10 physical science lessons and also make field notes that will be analyzed after the lessons. All lesson observations will be conducted during normal physical science lessons. And the video recorder is used to help me with data that I can observe several times in order to facilitate an in-depth analysis of the lessons observed, and this video recorder will be placed at the back of the classroom so as to limit disturbance of teaching and learning. I will also like to interview three learners in the Grade 10 physical science classroom to understand how best physical science teachers should teach the topic of Electricity and Magnetism. If it happens that your child forms part of these three learners (to be chosen after the teaching), I request for your permission to allow your child to participate in this interview.

The reason why I have chosen your child's class is because your child is in Grade 10, doing physical science and is taught by the physical science teacher who has agreed to participate in this study. However, your child will not be required to do anything additional rather than being present in his/her physical science lessons as he/she normally does.

I request for your permission to sit during your child's physical science lessons on Electricity and Magnetism topic to observe and video record their lessons. I will not actively participate in the lessons. Your child will not be advantaged or disadvantaged in any way. S/he will be reassured that s/he can withdraw his/her permission at any time during this project without any penalty. There are no foreseeable risks in allowing your child to participate and your child will not be paid for this study. Your child's name and identity will be kept confidential at all times and in all academic writing about the study. His/her individual privacy will be maintained in all published and written data resulting from this study.

All research data will be kept safe at Wits School of Education and will be destroyed between 3-5 years after completion of this project. Please let me know if you require any further information.

Thank you for your help. If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email Shaun.Schoeman@wits.ac.za

Yours Sincerely,

Sphamandla Zulu	***Thabisile Nkambule***
spha.i.zulu@gmail.com	*Thabisile.Nkambule@wits.ac.za*
Tel: 0117173496	*Tel: 0117173049*
Cel: 0785493480	*Cel: 0734935098*
*[**Researcher**]*	*[**Research supervisor**]*

INCWADI YOLWAZI YOMZALI

USUKU: 01 Nhlaba 2019

Siyakubingelela mzali

Igama lami ngingu Sphamandla Zulu ngenza iziqu zobudokotela kumkhakha wezemfundo (phecelezi PhD in education) esikoleni sokuqeqesha othisha enyuvesi yase Witwatersrand. Ngenza ucwaningo ngokufundiswa nangokufundwa kwe-Physical Science ezikoleni ezisemaphandleni. Lolucwaningo lusihloko sithi: **―Exploring Grade 10 rural teachers' and learners' teaching and learning of Electricity and Magnetism in Vryheid schools, KwaZulu-Natal Province‖**.

Lolucwaningo lami lubandakanya ukubukela ufundiswa kanye nokufundwa kwesihloko i-Electricity ne Magnetism esifundweni se-physical science. Izifundo ezibukeliwe zizoqoshwa phansi ngenhloso yokubhekelela nokucwaninga okwenzeka egumbini lukufundela i-Electricity kanye ne Magnetism. Njengomfundi webanga leshumi, umntwana wakho uzobe engalindelekile ukuba enze okweqile kunalokho ahlale ekwenza, njengokuthi abekhona egumbini lakhe lokufundela. Njengomcwaningi ngizoma emuva egumbini lakhe lokufundela ukuze ngingaphazamisi ukufunda kanye nokufundiswa komntwana wakho. Ukuzibandakanya komntwana wakho kulolucwaningo ngeke kumuphe noma kumuncishe amamaki ezifundweni zakhe.

Ngicela ukuba ungiphe imvume yokuba segumbini lapho umntanakho efundela khona i-physical science ukuze ngibhekisise ukufundwa kanye nokufundiswa kwesihloko se-―Electricity and Magnetism‖. Nginxusa ukuba uvumele umntanakho ukuba ahlanganyele kulolucwaningo lami ngokuthi abekhona egumbini lakhe lokufundela i-physical science uma ngibhekisisa futhi ngithwebula (video record) ukufundwa kanye nokufundiswa kwesihloko i- Electricity ne Magnetism. Ngicela ungiphe imvume yokuthi ngithwebule ukufundiswa kanye nokufundwa kwe Electricity ne Magnetism ngesikhathi esijwayelekile sokufundwa kwalesisihloko. Umntwana wakho akaphoqelekile ukuba azibandakanye kulolucwaningo, okusho ukuthi uma engafisi ukuhlanganyela kulolucwaningo engasho kanjalo futhi ngeke ngimuthwebule egumbini lokhe lokufundela i-physical science. Ngifisa futhi ukuxoxa nabafundi abathathu egumbini lokufundela, ukuze ngiqondisise ukuba sifundiswa kanjani futhi sifundwa kanjani isihloko se Electricity ne Magnetism ngoba abafundi banenkinga ngaso kwibanga le shumi nambili. Uma kwenzeka ukuba umntanakho usohlweni lwabafundi abathathu, ngicela ukuba ungiphe imvume yokuthi ahlanganyela ngokuzithandela kwakhe, futhi ungiphe imvume yokuba ngixoxe nawe. Okubalulekile, uma kwenzeka maphakathi ukuba akasafisi ukubandakanyeka kulolucwaningo, lokhu kuyisinqumo sakhe, uvumelekile ukuba enze kanjalo futhi uma enze njalo ngeke acikelelwe phansi noma aphathwe kabi nanoma ngayiphi indlela.

Angeke ngisebenzise ulwazi oluvela kumfanekiso othwetshuliwe nanoma yikuphi, ngaphandle kokusetshenziselwa kwenjongo yalolucwaningo. Ngakho-ke, umntanakho evela kulomfanekiso othwetshuliwe ngeke abonakale ukuba ungubani futhi negama lakhe ngekelisetshenziswe, kanye nobuso bakhe buyofihlwa njalo ukuze kungabonakali ukuba ungubani. Lonke ulwazi ngaye luzogcinwa luphephile futhi luyimfihlo kuwo wonke umbhalo ngalolucwaningo. Kanti okunye, lonke ulwazi oluqoqwe kulolucwaningo luzogcinwa endaweni ephephile kakhulu esikoleni sokuqeqesha othisha enyuvesi yase Witwatersrand, bese luyabhubhiswa eminyakeni emihlanu emva kokuphothulwa kwalolucwaningo.

Ngiyojabula kakhulu uma ungavumela umntanakho ukuba ngisebenzisane naye kulolucwaningo. Uma kukhona ofuna ukukwazi mayelana nalolucwaningo noma ukubandakanyeka komntanakho, ungaxhumana nami noma abaqondisi balolucwaningo kulemininingwane eshicilelwe ngezansi. Lolucwaningo luzobhalwa lube umbiko futhi luzobakhona kumtapo wolwazi wasenyuvesi yase Witwatersrand. Uma ufisa ukuthola isifinyezo salombiko, ngiyojabula kakhulu ukukuthumelela wona. Uma unokukhathazeka noma unezikhalazo eziphathelene nokuziphatha kwalolucwaningo, wamukelekile ukuxhumana ne - University Human Research Ethics Committee (Non-Medical), ocingweni oluthi +27(0) 11 717 1408, imeyili Shaun.Schoeman@wits.ac.za

Abazithobayo,

Sphamandla Zulu *Thabisile Nkambule*
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Cel: 0785493480 *Cel: 0734935098*
*[**Umcwaningi**]* *[**Umqondisi wocwaningo**]*

PARENT CONSENT FORM

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called: ***"*Exploring the teaching and learning of Grade 10 Electricity and Magnetism in Vryheid rural schools, KwaZulu-Natal Province*"***

I, _________________________the parent / guardian of _______________________

Permission to observe my child in class	**Circle one**
I agree that my child may be observed in class.	YES/NO
Permission to be videotaped	
I agree my child may be videotaped in class.	YES/NO
I know that the videotapes will be used for this project only.	YES/NO
Permission to be audiotaped	
I agree my child may be audiotaped during the interview	YES/NO
I know that the audiotapes will be used for this project only	YES/NO
Permission to be interviewed	
I agree my child may be interviewed for this study.	YES/NO
I know that my child can stop the interview at any time and don't have to answer all the questions asked.	YES/NO

Informed Consent
I understand that:

- My child's name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- He/she does not have to answer every question and can withdraw from the study at any time.
- He/she can ask not to be audiotaped, photographed and/or videotaped
- All the data collected during this study will be destroyed within 3-5 years after completion of the project.

Sign______________________________ Date____________________________

IFOMU LEMVUME YOMZALI

Ngicela ukuba uphendule loluhla lwemibuzo elandelayo ukukhombisa ukuzimisela ukuvumela umntwana wakho ukuthi abambe iqhaza kucwaningo olusihloko sithi: **―Exploring Grade 10 rural teachers' and learners' teaching and learning of Electricity and Magnetism in Vryheid schools, KwaZulu-Natal Province‖**

Mina (igama), __________________________umzali noma umbheki ka ____________________

Imvume yokubhekelela umtwana wami egumbini lokufundela sekela okukodwa
Ngiyavuma ukuba abhekelelwe umntwana wami egumbini lokufundela. YEBO/CHA

Imvume yokuthwetshulwa
Ngiyavuma ukuba umntwana wami angathwetshulwa egumbini lokufundela. YEBO/CHA
Ngiyazi ukuthi umfanekiso othwetshuliwe uzosetshenziselwa lolucwaningo kuphela. YEBO/CHA

Imvume yenxoxo nothile
Ngiyavuma umntwana wami akabe nenxoxo nothile kulolucwaningo. YEBO/CHA
Ngiyazi ukuthi umntanami engayimisa inxoxo nothile nomcwaningi nanoma ngabe yisiphi isikhathi socwaningo futhi akaphoqelekile ukuba aphendule yonke imibuzo ebuzwa kwinxoxo nothile. YEBO/CHA

Imvume yokuqoshwa kwenxoxo nothile
Ngiyavuma ukuthi iqoshwe inxoxo nothile YEBO/CHA
Ngiyazi ukuthi ukuqoshwa kwenxoxo nothile yomntanami nomcwaningi kuyosetshenziselwa lolucwaningo kuphela YEBO/CHA

Imvume yokwaziswa
Ngiyaqonda ukuthi:

- Igama lomntanami kanye nemininingwane yakhe izogcinwa endaweni eyimfihlo futhi ephephile. Kanti futhi igama lakhe kanye nelesikole sakhe angeke aziswe emphakathini, kodwa umcwaningi kanye nalolucwaningo luzosebensiza amagama mbumbulu ukukhuluma ngesikole kanye nomntanamani.
- Akaphoqelekile ukuba aphendule yonke imibuzo kulolucwaningo futhi engahoxisa iqhaza lakhe kulolucwaningo nanoma yinini.
- Engacela ukuba engathwetshulwa noma engaqoshwa inxoxo nothile yakhe nomcwaningi
- Lonke uhla lwemininingwane yalolucwaningo luzobhubhiswa esikhathini esiyiminyaka emihlanu emva kokuphothulwa kwalolucwaningo.

Isignesha ________________________________ Usuku______________________

Appendix 5: INFORMATION SHEET FOR TEACHERS

DATE:

Dear Sir/ Madam

My name is Sphamandla Innocent Zulu and I am a PhD student in the School of Education at the University of the Witwatersrand. I am doing research on teaching and learning physical sciences, specifically focusing on **―Exploring the teaching and learning of Grade 10 Electricity and Magnetism in Vryheid rural schools, KwaZulu-Natal Province‖**. Electricity and Magnetism is reportedly a challenging topic to most physical science learners, hence this research study in gaining insights into how physical science teachers teach it and thereafter learners learning of the topic.

My research involves observing and video recording your physical science lessons when teaching the topic of Electricity and Magnetism. As such, I request to observe and video record all of your lessons on Electricity and Magnetism. The video recorded lessons will be analyzed for the purpose of this research study. My research will also involve participating in a 20-40 minutes interview which will be based on the observed lessons and on your general understanding of the nature of science, its teaching including the teaching of Electricity and Magnetism and any other factors that either enhance and/or hinders the effective teaching of the topic in question. I then wish to interview you after school hours so as to not inconvenience your school teaching hours. This interview will be audio recorded for quality word-to-word conversation. Lastly, I would like to also watch some segments of your observed lessons (video recorded) to understanding the reasoning certain practices in your classroom. Both video recorded observations and audio recorded interviews will be transcribed verbatim and analyzed for the purpose of this research study, and possibly for presentation at a conference and/or published as a general paper in a journal.

The reason why I have chosen you and your school is because you are a Grade 10 physical science teacher who has taught physical science at least for three years. Your school has been chosen because it is located in the rural part of Vryheid town and it has a Grade 10 physical science class. I am requesting that I come to your classroom to observe (video record) your Grade 10 physical science lessons and interview (audio recorded) you thereafter all your lesson observations. Your name and identity will be kept confidential at all times and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study. All research data will be kept safe at Wits School of Education and will be destroyed between 3-5 years after completion of this project.

You will not be advantaged or disadvantaged in any way. Your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating and you will not be paid for this study. Please let me know if you require any further information.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email Shaun.Schoeman@wits.ac.za

Yours Sincerely,

Sphamandla Zulu	***Thabisile Nkambule***
spha.i.zulu@gmail.com	*Thabisile.Nkambule@wits.ac.za*
Tel: 0117173496	*Tel: 0117173049*
Cel: 0785493480	*Cel: 0734935098*
[Researcher]	***[Research supervisor]***

TEACHER CONSENT FORM

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: ***"*Exploring the teaching and learning of Grade 10 Electricity and Magnetism in Vryheid rural schools, KwaZulu-Natal Province*"***

I, ____ agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. Please circle the relevant options below:

Permission to observe you in class	**Circle one**
I agree to be observed in class.	YES/NO
Permission to be audiotaped	
I agree to be audiotaped during the interview or observation lesson	YES/NO
I know that the audiotapes will be used for this project only	YES/NO
Permission to be interviewed	
I would like to be interviewed for this study.	YES/NO
I know that I can stop the interview at any time and don't have to answer all the questions asked.	YES/NO
Permission to be videotaped	
I agree to be videotaped in class.	YES/NO
I know that the videotapes will be used for this project only.	YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotape
- All the data collected during this study will be destroyed within 3-5 years after completion of this project.

Sign______________________________ Date_____________________________

Appendix 6: LETTER TO THE PRINCIPAL

DATE:

Dear Principal

My name is Sphamandla Innocent Zulu, I am a PhD student in the School of Education at the University of the Witwatersrand. I am doing research on physical sciences teaching and learning, specifically focusing on **―Exploring the teaching and learning of Grade 10 Electricity and Magnetism in Vryheid rural schools, KwaZulu-Natal Province‖**. Electricity and Magnetism is reportedly a challenging topic to most physical science learners, hence this research study in gaining an insights into how physical science teachers teach and thereafter how learners understand the topic.

My research involves observing Grade 10 physical science lessons on the topic of Electricity and Magnetism. Both teachers and learners will be observed from the beginning till the end of teaching and learning of this topic. All observed lessons will be video recorded. Following the classroom observations, I will have one interview with the observed teacher, which will be based on the observed lessons and their general understanding of science teaching. In addition to the teacher, I will interview 3 learners from the observed classrooms. The interviews will take approximately 25 - 40 minutes for teachers; 10-15 minutes for learners and all interviews will take place after school hours or during break time. These interviews will be audiotaped and then both video recorded lessons and audiotaped interviews will be transcribed verbatim and analyzed for the purpose of this research study, and possibly for presentation at a conference and/or published as a general paper in a journal. All lesson observations will take place during normal teaching time, in normal classrooms without any additional requirements from/to the teacher. Video recording all lessons is necessary to capture both teachers' and learners' approaches (writing on the chalkboard, learner-learner or teacher-learner interactions), to minimize disturbance of the lessons, and to also watch the observed lessons several times so as to facilitate in-depth analysis of the observed lessons.

The reason why I have chosen your school is because it has a grade 10 physical science class and it is situated in rural parts of Vryheid town, KwaZulu-Natal. I am interested in finding out how teachers and learners teach and learn Electricity and Magnetism in your school to enhance understanding of science concepts in the topic. I am inviting your school to participate in this research voluntarily and the school is not going to be disadvantaged in any way. The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid for this study. The names of the research participants and identity of the school will be kept confidential at all times and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from this study. All research data will be stored safely at Wits School of Education and it will be destroyed between 3-5 years after completion of the project.

Please let me know if you require any further information. I look forward to your response as soon as is convenient. If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email Shaun.Schoeman@wits.ac.za

Yours Sincerely,

Sphamandla Zulu	***Thabisile Nkambule***
spha.i.zulu@gmail.com	*Thabisile.Nkambule@wits.ac.za*
Tel: 0117173496	*Tel: 0117173049*
Cel: 0785493480	*Cel: 0734935098*
*[**Researcher**]*	*[**Research supervisor**]*

Appendix 7: Classroom observation schedule

I took the role of a non-participant observer. The following were the specific points of interest during classroom observations:

- Classroom communication: Is the classroom communication a one way transmission of content from teacher to learners or teacher-learner and/or learner-learner interactions is encouraged?
- What forms of representations (macro, submicroscopic and/or symbolic) are used by the teacher and how are these used?
- Does the teacher explains (explicitly or implicitly) or provide the correct understanding of the Electricity topic in relation to what is difficult to teach or learn, and/or confronts any learner misconceptions?
- Is there a clear teaching approach that the teacher uses? Including observable patterns of teachers‘ discourse.
- What are learners doing when the teacher talks, including how the teacher works with learner prior knowledge?
- What tasks, if any, are teachers utilising in class and how are these used to promote scientific understanding?

Appendix 8: Sample of Classroom Observation transcripts for Amanda and Sipho

Amanda's lesson 1

00:28: 01:38: Teacher: Yesterday we had finalized electrostatics, I know that you know that there are two types of charges. Which are the two types of charges Grade 10? Hands up! (learners raising hands). Miss Ayanda[39] (learner picked from those who had raised their hands).

Learner: positive and negative charges

Teacher: Yes we do have the charges, positive charge as well as negative charges. As we know that in electrostatics, this is a form of <u>electricity which is not moving</u>, where charges are stationary and then in order to have a charge in electrostatics where electric charges are not moving we said we can accumulate a charge of an uncharged material or insulators, where we find that an object is said to be neutral and then we want to charge positive or negative. So we said there, you can charge through rubbing or through friction. [<u>*The teacher is talking without paying attention to whether learners are listening or not, learners are forced to just sit and listen to the teacher talking -*</u>].

01:58 – In Grade 9 they do talk about the form of electricity which is moving what do we call the form of electricity which is moving, which has got charges that are moving? In grade 9, do you remember? (no response) where we talk of the continuous movement of charges so that is electric current, this is what we learnt in grade 9. I want us to look at something that we looked at in grade 9, we talked about electric circuits, this is grade 9 work. So here with me I have a circuit board, this is my circuit board (showing the circuit board to learners but only from the front of the class). And here I got some components which are found in a circuit as you know that in a circuit we arrange cells, light bulbs, connecting wires in order to see the flow of current. So this is my circuit board (lifting it up again) and here in grade 9 we talk about the light bulb I'm going to show you the components first so that it will be easier. These are the components, the light bulb (lifting it up to show to learners)

We do have connecting wires (shown but were not visible to the camera), and then we do have a cell holder (shown and quickly returned back) and then we know this is a (learners: a cell) this is a cell, when we've two or more cells together they form a battery. Ok that is interesting. And then in grade 9 you also talked about components which are found in a circuit, this is a volt..(unfinished) an ammeter, an ammeter measures current and also recap from grade 9, we talked about a voltmeter, we said this is

[39] Pseudonym given to the learner.

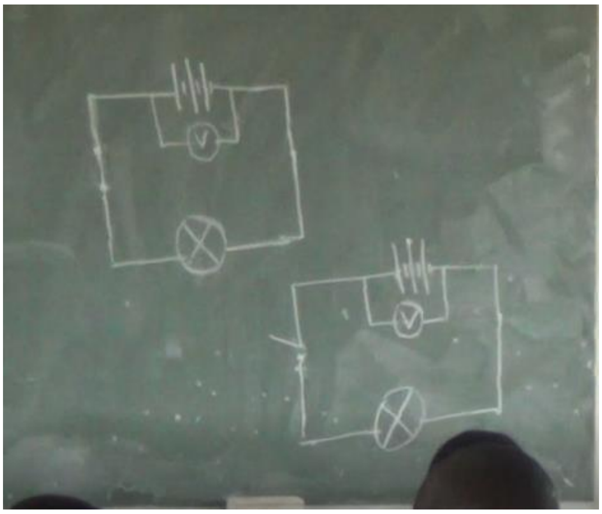
an instrument which measures what, potential difference, and then we said it is always connected in parallel an ammeter is connected in series. That is a grade 9 work that we have done with the learners who were with me. These components have got symbols to represent with, we have symbols. Now let‘s talk about electric circuit first.

04:45 - When you look at electric circuit, what is the role of electric circuit? It allows charges to move through. If I can connect all these components here and then what will happen, the charges will move and know that those charges that are moving, these are the positive charge as well as negative charge. And then how is this flow of charges, we said it moves from positive to a negative terminal of a battery. This is a positive terminal of a battery (showing and pointing at the positive terminal of a 1.5V cell) and a negative terminal of a battery (showing and pointing at the negative terminal of 1.5V cell), so that we call it conventional current (showing the movement from positive to negative).

06:49 – 07:45: We do have a switch, you remember a switch? (learners: yes). Right we do have a switch, a switch can be opened or closed as you please. You can open a switch, I do have a switch with me here and then its role...this is a switch you can (showing a circuit switch to the class). You close the switch and then you find that the light will glow, if you open the switch there will be no flow of current and the bulb will not glow. Alright, that is what is happening here (pointing at and going towards the classroom switch), now the switch is closed and then you see current is flowing [and then teacher switched off the lights] and then I close, I‘m closing the switch but now the switch is open, you see [then switching on the lights] if its closed, there is a flow of current.

10:50 – 11:15: Now, as you are talking about a battery, a <u>battery is a source of energy</u> so it has got that force which drives what, charges. So in other words, a <u>battery supplies what is known as potential difference</u>, we name it potential difference or voltage.

12:55 – 14:13: Let me make a diagram which will illustrate a cell which is said it is connected and is complete [the teacher drew the diagrams below]. This is my circuit diagram.

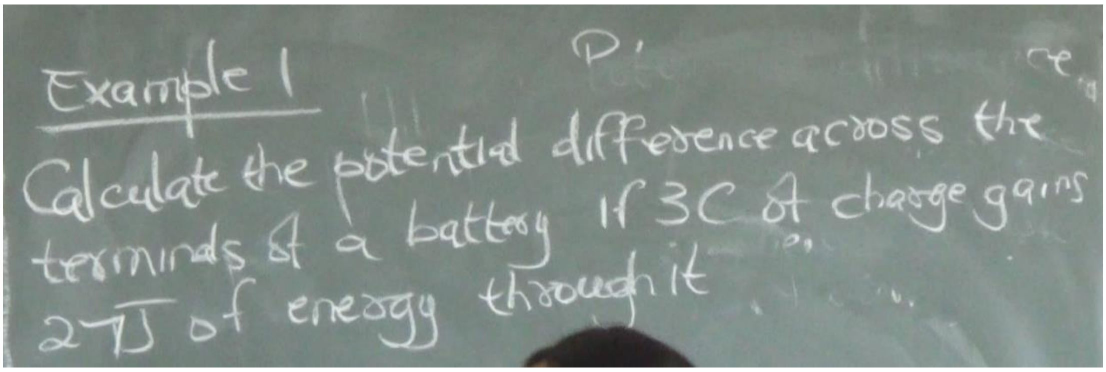


[Referring to the drawn diagrams]

14:16 – 15:30: So now we want to differentiate between the two of these circuits, here we do have what? (referring to the first diagram) [learners chorus: switch] what can we say about the switch between the two circuit diagrams? So for circuit diagram A, this is my A and this is my B [labelling the diagrams as follows]. What can you say about the switch? Say something about A. [pointing at a learner]. (learner: the switch is closed). The switch is closed, so what tells you when the switch is closed? (some learners chorusing: there is a flow of current). There is a flow of current, so here there is a flow of current (writing next diagram A) and then what did we say about the switch? (learners: its closed). The switch here is closed (verbalizing as she writes it on the board). Diagram B! (learners: the switch is open). So here we have open switch (verbalizing as she write it on the board). Say something about this circuit. (learners : there is no flow of current). There is no flow of current.

15:48- 16:22: Now if the cell is completely connected you will find that there is a flow of current like diagram A, like diagram A. so if there is a flow of current like diagram A, we talk of potential difference. So now we are talking about potential difference [saying this as she writes on the chalkboard].

16:26 – Here we got a circuit but now we find that the charges are not moving so there is no flow of current. Like here I do have my battery (pointing at diagram B), my battery is there, it‘s the voltage, it is not being used. So now we are talking the emf. We are talking about the potential difference (pointing at diagram A), and then we are talking about emf (pointing at diagram B). so in other words, when we look at the emf, we are talking about maximum voltage that a battery can deliver. So if you go to town, you buy your cells (showing a 1.5V cell) its 1.5V, or 3.5V. if these cells are not being used we say it has got emf because it is not used but if you take that battery and then now you connect it completely in such a way that the charges will move, we said they move from positive terminal to the negative terminal. And then now, we will find that we are talking about potential difference. So in other words, now it means the battery is working so charges now are moving, so that's the difference between emf and potential difference. I am going to write that on the board. So you have to know in grade 10, what is the definition of potential difference, what do we mean when we talk of potential difference.



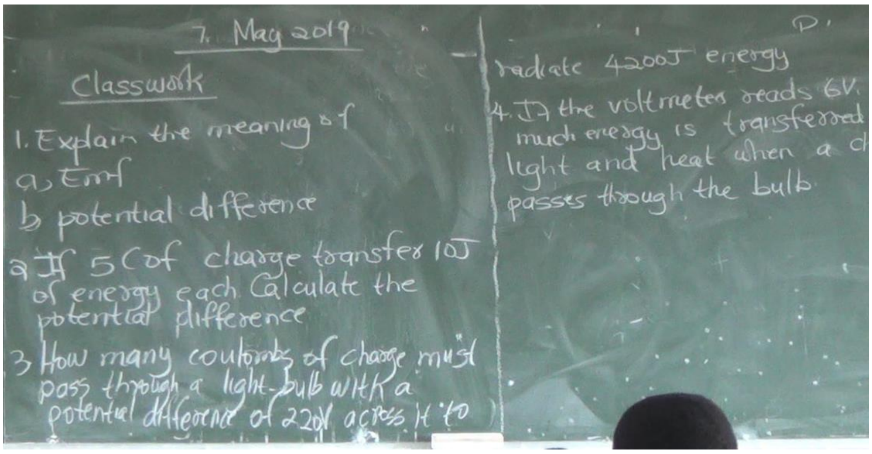
Now if 3C, you are given that is your data, 3C is what? (learners: Charge) the charge in Coulomb. So in other words we are given our charge. Again 27 Joules, you know the symbol J, its for? (learners mumbling) work, so this our work done. So we do have our charge, we do have our work done. So it is easy for us to calculate potential difference using the formula V=W/Q (as she writes the formula on the board). What is our work done, 27J , what is our charge, 3C the you divide, engage yourself in calculations Grade 10 use your calculator 27 divided by 3 (learners: its 9). Because we are not going to write 9, this is not maths but you are calculating what? Potential difference, so the units of potential difference are the Volts. So it is not correct to write only 9…ok that is example number 1, is it clear? (learners: yes) lets do the last one.

The teacher writes the above on the chalkboard and then says the following:

This is another example, we have to engage ourselves in doing calculations based on potential difference, every learner must be in a position to do calculations on potential difference using the formula which is V=W/Q. Let's check the example we are given here, what is the potential difference so it rings on your mind that you are going to calculate potential difference and you know the formula for calculating the potential difference. A potential difference of a light bulb if a charge of 17.5 Coulomb pass through it and radiate 4200 Joules of energy. Who can tell me, what are we given? Hands up! Look at the example given and then give me what is given. (*silence*) what is given? (*she then calls few learners individually by surname for the response but there was silence*) there on the example look at the data, what are you given? (learner: you are given the charge) you are given the charge then what? (learner: work done in joules) work done in joules so we can calculate the potential difference, can you just do that calculation I am going to give you 2 minutes so that you can share if you have done it correctly. You can work with someone next to you to if you do understand because this is straight forward.

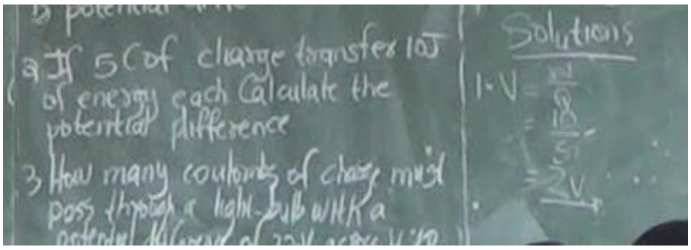
After few minutes

Others are finished, what did you get? Lets see, using the formula V=W/Q, what is our W? (learners: 42) what is our charge flowing? (learners: 17.5) and if you divide this… what did you get (learners responded but inaudible but there were mixed answers) alright clap hands for all those who got it correct. But I‘m not happy because they just doing it randomly, I had to check using activities so that I can see if you have mastered what we have learnt today. Now lets summarize this we have been talking about electric circuit, we have been saying they allow charges to move through, we know the types of charges and then we know about the components of a circuit. Now I want you to answer this question, what is the meaning of the emf? Hands up (learners mumbling) hands up! (learner: the work done per unit charge by a battery) she is saying the work done per unit charge by a battery. Ok! What others say? (silence) emf! Emf! She‘s saying the work done per unit charge by a battery, what others say about emf? (silence) (teacher then calls some learners by names asking what is emf) (learner: the maximum voltage of the battery) the maximum voltage of the battery or what did we say about emf? (looking at the notes from the chalkboard) (silence) emf! Emf you are saying it‘s a maximum voltage of the battery or emf is equal to potential difference measured across the terminals of the battery where no charges are flowing in the circuit (pointing and reading from the chalkboard). Ok what is the terminal potential difference? In other words you need to know these definitions grade 10. What is the terminal potential difference? Hands up! (silence) (learner reading from her exercise book – notes: it is the energy transferred per unit electric charge through…inaudible) yes it is the energy transferred per unit electric charge through it (pointing and reading at the notes on the chalkboard as she talks). We said both emf and potential difference are measured in which units? Hands up! (Learner: in volts) they are measured in volts. What is the instrument which is used to measure potential difference? Give me the name of the instrument that we use to measure potential difference. (silence) let‘s see, we measure potential difference using which instrument? I have been showing you the instruments here, the one which measures potential difference! (Learner: it‘s a voltmeter) it is a voltmeter. How do we connect a voltmeter? How is it connected, is it connected in parallel or in series? (majority of learners saying in series and others saying in parallel). It is always connected in parallel. Now let us write our classwork.



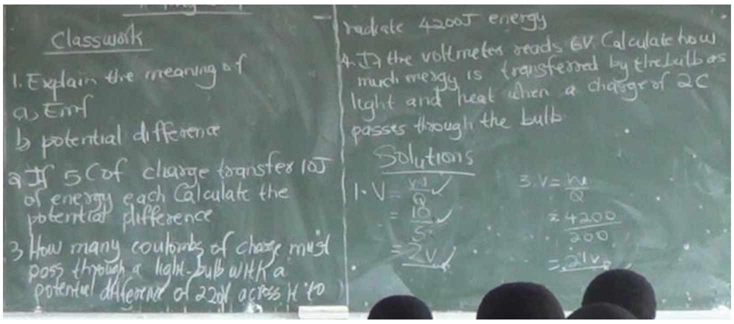
After writing the questions down, the teacher moves around looking at where learners are writing, she then after waiting time asked for learners inputs so she writes the solutions on the chalkboard.

Bathini ku number one, the definition, no one? What is it, emf? Is the voltage measured across the terminals of a battery when there is no current flowing. And then potential difference? Khulumani! What is it? (learners mumbling – inaudible of what they were saying) the energy…(learners: transfer per unit charge) ok, we are done with number 1. So lets look at number two, who can do number two for us on the chalkboard? (*When responding to the second question of the activity, the first learner wrote:*



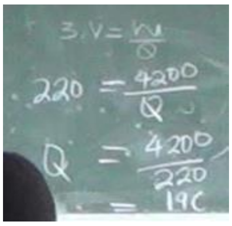
Now using the formula V=W/Q, our work done is (learners: 10) its 10 and then our charge (learners: five) is five. When you divide, you get 2, so this is the answer.

Learner wrote the response to third question

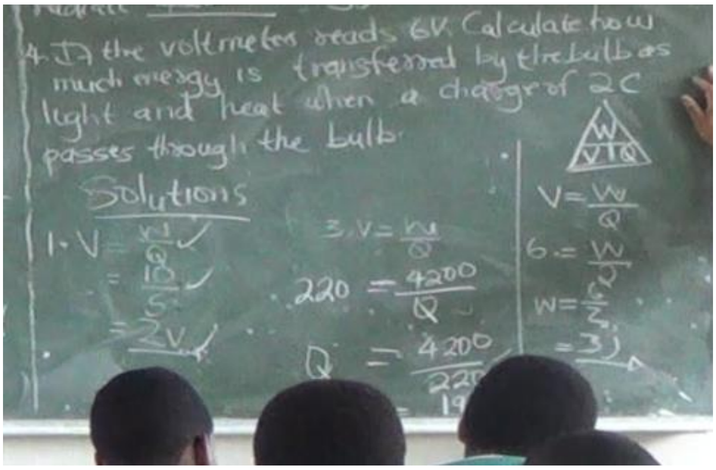


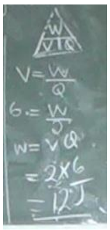
Number three, what does it require? How many coulombs, it is the question. It wants what, the charge not potential difference. In order words you are not given the charge, we are given here the potential difference and energy (*underlining the two also from the question and then she erased what was written by the learner on the board*). What is our potential difference, 220, what is our work done 4200, Q we are not given the charge. How do we calculate the charge, we say 4200 divided by 220, it will be (learners: (19 coulomb)

The corrected version of the response became:



learner wrote on the chalkboard as the response to question number four





We normally use this (drawing the triangle of W, V, Q) So now they are looking at how much energy, they are looking at work (hiding the W symbol with a hand from the drawn triangle leaving V side-by-side with Q) so for work it will be V times Q. It will be 2 times 6, it will be 12 joules.

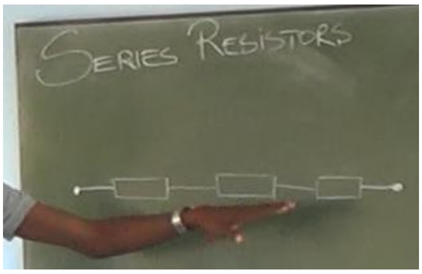
…………………………The end of the lesson………………………………….

Sipho’s lesson 2

I gave you work the last day, let‘s see how you were supposed to do that. Was there any problem in the work that I gave you? (learners responding chorusly: no) so you were supposed to number 72-80.

In solving the first question the teacher says: so you firstly write your data so this is what you‘re given, you are given the find that‘s the question we are looking for potential difference which is V and 4 is the resistor the resistor is capital letter R and then this is 15 Ohm‘s. And then it carries current, a current of 4amperes. Then to solve this, which equation do we use to solve this? Yes (learner responded but was inaudible) Resistance is equal to potential difference over current. We do have resistance of which is 15Ohm‘s, do we have potential difference? No, that‘s what we are looking for, do we have current? Of course yes we have current. This (*current*) is dividing on this side coming this side (*other side of the equal sign*) it‘s going to multiply. Which means our potential difference is equal to 60, six zero which is 60V.

The next thing according to our exam guidelines, we now have to look at the combined resistors (*teacher looking through and reading from his exam guideline on the teacher table in front of the classroom*) so if we talk of the combination of resistors now we look at two or more resistors. So now in combinations we have (the teacher leaving the front desk facing the chalkboard and writes series resistors) so now we have to look at series (learners: circuit) resistors, series resistors or ehhhm yes at the top of series circuit we talk of, we look at resistors and specifically resistors that are in series (as the teacher emphasizes on the series resistors rather than series circuit, he facing the learners and not writing on the board). So resistors in series this is on page 15 of your exam guideline. So if we have resistors that are in series, this is a symbol for a resistor (teacher drawing three resistors connected in series). Then these resistors are in series, these resistors are in series. Like if you look at the cells, cells of a torch they are connected in series because each cell is following the other cell so they are connected in series. Same thing with resistors if they are connected like this, they are connected in series:



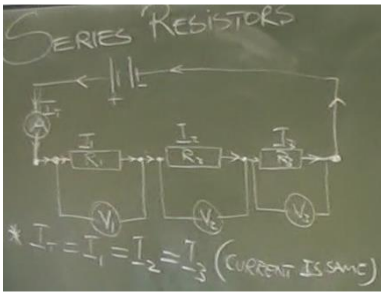
And then if this is resistor number 1, this is resistor number 2 and then this is resistor 3 (teacher labelling the resistors in their orders). So definitely for a series circuit, lets say put a battery here, let me draw ama-cells, so here you have two cells that are connected in series, they are in series because they follow each other. So now this is series circuit, if I may put here an ammeter (before the resistors from the positive terminal of the battery), the ammeter will be here and it will be connected in series. And then now, if I want to connect a voltmeter across each resistor , if I want to measure the potential difference that is here (teacher using his hands to point across a resistor):

So I will connect a voltmeter across each resistor which means each voltmeter must be connected in (learners mumbling: in series) PARALLEL (*teacher emphasizes through a raised voice*) voltmeter is always connected in parallel so this is voltmeter number one, its going to measure the potential difference across resistor number one:

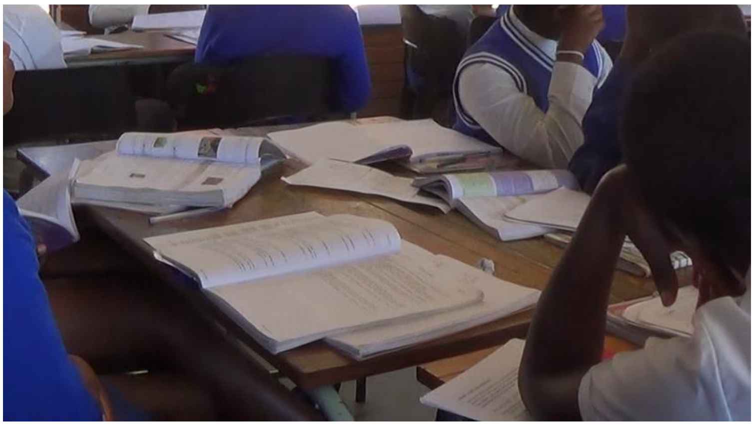
And then now secondly, if I want to measure the potential difference across this (pointing at resistor number two) then I am going to connect another voltmeter here and this will be voltmeter number two. And then lets connect the last one across voltmeter number three (learners finishing off with the teacher: three), so then those are the potential difference, those are the potential difference.

So now the thing that you need to know about resistors that are in series, one: about the current it flows from, that‘s the principle of conventional current, it flows from positive to the negative and looking at current because current is the flow of charges, its not easy to deal with the current because you cannot say this is the current this is where the current is (teacher pointing at the circuit) because we talk of charges. But then we assume that when you work out your circuit the first thing that you do, you look at the circuit and then because ama-circuits awafani (are not the same) we are doing series right now we are going to move to the next which is parallel but to see if resistors are series, the first thing that you do you put the arrow (teacher drawing an arrow from the positive terminal of the battery pointing towards the ammeter then to the resistors-starting to pass through from the first resistor) your arrow is going to indicate your current which means if it starts from positive then its going to face this direction (pointing towards an ammeter). Then whatever the current can pass you put the arrow, remember we said current cannot go where…, it goes where i-resistor incane, where there is high resistance it doesn‘t go there. Which means if we trace the current across the ammeter, does the ammeter have a high or low current? (teacher quickly responding to himself: it has low) so which means current izoqonda lapha angisho (it will go through the ammeter as the teacher draws the line passing through the ammeter) ifike yenzenjani, indlule. Here is our current (indicating through drawing that current has passed through the ammeter towards the resistors) doe the current take this direction? (pointing at the voltmeter across the first resistor) (teacher quickly responding to himself again: no) why? Simply because this one (pointing at the drawn symbolic voltmeter) has a high resistance, we do not worry ourselves ayisayi lapha (pointing at the voltmeter) iqonda kwi-resistor. Then its going to pass this resistor (first resistor) and go through this resistor (second resistor) it doesn‘t go to this voltmeter because it has high potential difference (learners loudly: high resistance) then yedlule nansi ya iyekuleya resistor, ayiyinjalo lapha okune high poten…okune high resistance khona, so ayiyi kuma voltmeter (learners are laughing). Current ezobe ingene la (pointing at the positive terminal), ikhona lapha eke yashintsha khona –current (learners: no) no lohku kuyiyo leya (pointing from the ammeter through the resistors) uyabona ukuthi ayikho lapha eke yaphazamiseka khona, yenzenjani iyedlula. So now what does it mean, current umangabe kuyi series, ama-resistors wakho umangabe ekwi-series current yakhona iyafana, uma ama-resistor wakho eku-series current iyafana azoba ne-current efanayo. Which means the current that is here (writing next to the first resistor) if its I_1 and then the current that is here if its I_2 because kusho ukuthi lana sizo-placer ini (pointing just before the first resistor), ammeter number 1, ammeter number 2 (between first and second resistors), ammeter number 3 (between second and third resistors) remember angenanjani (ammeters) series. Then if the current across resistor one is I_1 kusho ukuthi lena izoba I_2 and then I_3 (for resistor two and three respectively) and then here (on the ammeter before resistors) we have a total current. Mayisiphuma lana (after resistor 3) izophuma injani, ifana injengoba injalo, remember current esuke liana (total current from the positive terminal of the battery) kufanele ibuye njengoba injalo lana (negative terminal of the battery), uma iphume ingu-2 lana (positive terminal) kumele ibuye ingu-2 lana (negative terminal).

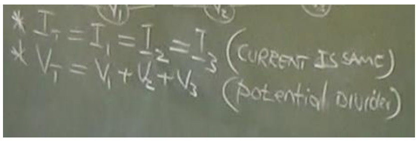
What does it mean, it means one, the current across the series circuit is the same, it means that $I_T=I_1=I_2=I_3$ (as the teacher talks he is also writng this on the chalkboard) the current is the same. So in series in resistors we say current is the same or is constant throughout the circuit:



Then the next thing, looking at the potential difference, the potential difference that is here (pointing at the first resistor) is not equal to the potential difference that is here (pointing at resistor 2) and not equal to the potential difference that is here (pointing at resistor 3). Remember when the potential difference comes back here (negative terminal) it must be the same also okusho ukuthi lena (by the power source – battery) singasho sithi iyi-total potential difference elingana nani, at this case ilingana ne-emf ngoba akukho internal resistance then ilingana ne-emf. So what is happening, lana the current is divided I mean the potential difference is divided, current is the same and potential difference is divided.

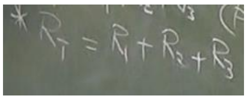


So what does that mean, it means that the total potential difference is equal to $V_1+V_2+V_3$. The current, if you combine this current it must give you the total current, it must give you the total current (learners finishing off what the teacher is saying: current). What does that mean, which means a series circuit is a potential difference divider, it‘s a potential difference divider so it divides potential difference



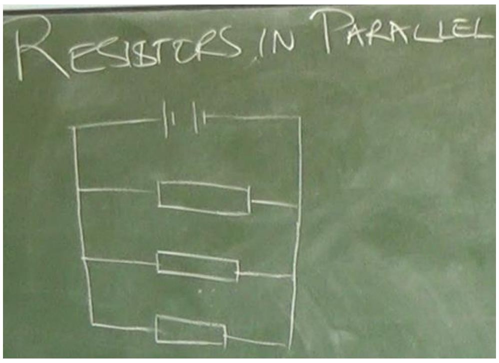
(as the teacher kept on mentioning total current being the sum of current, he actually potential difference being the sum of total potential difference) – Incongruence on what is said and what is written.

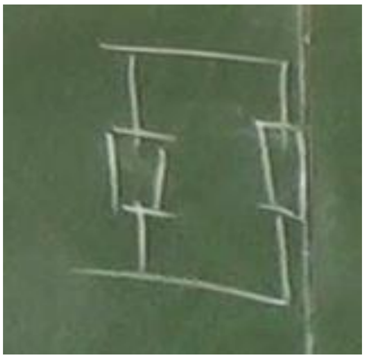
So it means if ama-resistors elingana uma ngabe bekungu 12 volts lapha (pointing at the total potential difference by the power source) if these resistors elingana azothatha potential difference elinganayo, they are going to split that 12 into equal parts but then if engalingani its going to vary according to the ratio. So for resistance, lama resistor lana (pointing at the three resistors) uma uwahlanganisa kumele akunike total resistance so which means the total resistance of the series circuit is equal to the sum of the resistance, so we simply add the resistors (as the talks he is writing the following on the chalkboard):



Teacher goes towards his front desk, pages through a document and says the following:

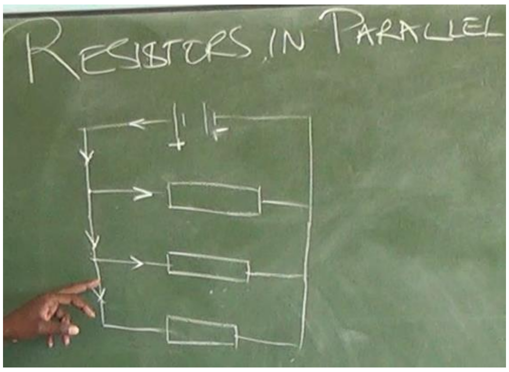
Let‘s look at parallel resistors, let‘s compare these with the parallel resistors so that we are going to understand this better. We need to compare this to the parallel resistor. Now resistors that are in parallel, so now if you have, take the same resistors (*as the teacher talks, he draws a circuit diagram in the following pictures*)



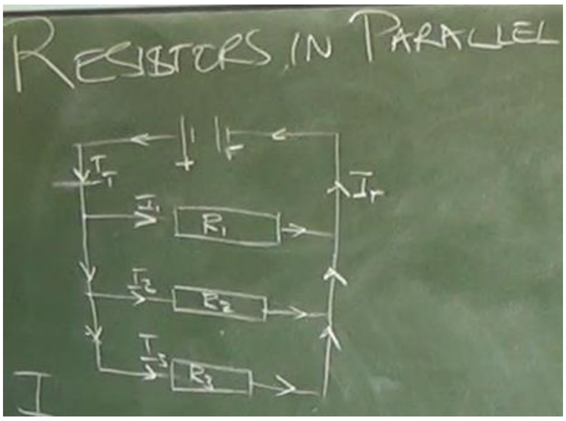


Now let‘s say we have these resistors now they are connected in parallel. It‘s not always that resistors will be arranged like this. It can also be like this (*drawing two resistors in the above pictures*), still these resistors are parallel. Then for you to make this easier for you because you are given the circuit in various ways so that you can see whether it is parallel or series, firstly look at the law of conventional current then now you start drawing your current with arrows (*indicating with arrows on the circuit in the following picture*). *Nansi iyahamba lana* (here it is moving) (*referring to current as he draws arrows*), *iyaqhubeka current mayifika la* (current continues when it gets here) (*pointing at the T-junction of the circuit*). Definitely some will take this direction (*indicating the direction to the first branch of the resistors from positive terminal*), *kuphinde kube khona eza ngakuphi* (and another one will take which direction?) [**Learners**: Straight].

Sipho: Once it splits, it means it is parallel, *yabona la akukho la ejika khona ihamba straight ku-series* (you see here, there is no point where it turns, it moves straight in series (*referring and pointing at the following pictures*). But here (*referring to the following picture*), there is some current going this way and there is some current continuing. The current here (current that went straight from the T-junction) *ayisafani nelapha* (is not the same as the one here) (*referring to current that went to the first branch, to R_1*). *Kukhona encane eshonelena* (there is a bit that went this direction) (referring to the first branch), and another one went this direction (*referring to the current that went straight from the T-Junction*).



These current *come together and do what?* [**Learners**: they meet]. They meet as current I_1, I_2, and I_3 to give total current on the other end towards the negative terminal (*in the following picture*). To see that resistors are parallel is easy if you are going to trace the current, if it splits then its parallel, definitely these ones are parallel (*pointing at the following picture*). Now since we talked of current, let's say you look at the current here we said it is the same but here (*pointing at the following picture*) current is not the same. We have R_1, we have R_2, we have R_3 (*labelling the circuit in the following picture*) and then definitely this is the total current (*labels total current just before it reaches the first T-junction*) and then this will be I_1 (*just next to R_1*), this will be I_2 (*next to R_2*) and this will be I_3 (*next to R_3*). So the total current that comes out from the positive terminal splits then when it goes back towards negative terminal after the resistors it becomes total current (*explaining using the circuit in the following picture*).



……………………………The end of the lesson…………………………

Appendix 9: Sample of VSRI transcript with teacher Sipho

Some sections of the recorded video lessons were watched by the researcher and the teacher and then questions arising from these were asked.

Teacher: It is bad the whole school, learners from Grade 8 to Grade 12, they don‘t pass, they don‘t pass! They are just stressing us.

Researcher: Why though, they don‘t want to study?

Teacher: They don‘t want to study. When you look at it, its like a culture that we go to schools, at the end of the day, whether we pass or not we don‘t care. They don‘t pay attention to anything at all. So we have a huge task as teachers.

Researcher: So I‘m just looking at the lessons we‘ve recorded with individual teachers with the aim of understanding their practices and their pedagogical choices.

Teacher: Refer to the lessons we did?

Researcher: Yes the lessons that I observed you teaching on. So we could play the whole video lesson but I will go to specific points where I would like to ask few things on. Just few things. Like here…(playing a video).

02:24 – other power source ? (learners‘ response - ―bulb‖). *What do you think led them to this response?*

Researcher: you heard what they say?

Teacher: they said bulb.

Researcher: Any idea as to why they said it‘s a bulb, what do you think led them to that?

Teacher: Ehhhh its like… I think, instead of listening they were watching what I was writing on the board because the time I asked, I was busy drawing. So…and then I draw a bulb but then I was asking them about power source and they answered saying it‘s a bulb. At this case, I think its that.

Researcher: They were looking at what you are writing.

02:47 – what you can use instead of a battery? *Why simplified or rephrased the question?*

Researcher: you saw they were struggling and then you now simplified the question, why so?

Teacher: I think from their answer, I noticed that…I didn‘t notice at the instant that they were following what I was drawing and then from their responses it was then that I realised they think because a circuit has this and then the following one be this and if I ask a question they would responded based on what is following and not using their knowledge and then I tried to simplify it so that they can see we are still on that. Yes

06:24 – meaning of rate explained

07:20 – *you involved your learners in giving you the SI units. Is it because they had done this work already?*

Teacher: I think we had done it, maybe (seems unsure). Or they considered their Grade 9 work because I did it there with them. But then I can't remember if we had done it here in Grade 10.

07:55 – meaning of ratio explained

09:49 – *you emphasized the function of an ammeter. Why?*

Teacher: For a difference that there is an instrument and there is an SI Unit, so that one is the instrument the one that is used to measure current. And amperes is an SI Unit

14:00 – *[spoke of Ω being equal to $V.A^{-1}$] And this came as part of their multiple choice in their June exam (common paper). Why was this emphasis during your teaching*?

Teacher: it's like.. yes I have seen this in their previous question papers but it's a question to define, they say define of which means you have to define it as a formula so you explain it in terms of units. They would say define 9 Ohms and you must refer to the formula, yes usually it's (formula) the definition.

Researcher: Ok in the sense of voltage and amperes?

Teacher: Yes voltage and amperes.

Researcher: I realized most of the learners did not getting this right in the exam.

Teacher: It's giving them a challenge!

15:20 – *remember in Grade 9. Were you with most of them in grade 9*?

Teacher: No they are from different schools. Because another thing that is usually a challenge you find that it (Natural Science) is taught by a life science teacher and find that maybe they focus more on the life science component.

Researcher: That is a challenging situation

Teacher: So it's better you do some of the things that are important do as if they never did it before.

For the desks analogy, what was its purpose?

Teacher: learners needed to visualize the relationship between resistance and current in a circuit.

19:36 – *For now why look at emf and pd as being the same? Ignore (internal resistance*)

Researcher: In Grade 10, we do not consider it then in Grade 12 they find it. This is to avoid a question that will say always, because they will just say always, its always. Then when they come this side and they would say the teacher said potential difference is equal to emf (electromotive force) but when they are in Grade 12 it is no longer the same. Its better that you make this clear now because it will be difficult for them to unlearn it

20:30 – *factors affecting resistance: what idea did you want them to know here, in relation to electric circuits*?

Teacher: these are the part of curriculum they must be covered. Usually they ask them in the multiple choice questions of the exam.

Researcher: So they have to do it in Grade 10?

Teacher: Yes.

Researcher: And when talking about them, you only look at these three at this Grade?

Teacher: yes. Temperature, surface area, and thickness…

27:48 – *importance of writing down the ―data‖, does it help learners with solving problems?*

Teacher: For substitution, for the start because they are still new to calculations (its their first time) but it helps them, individual write it so it can help them to pick the right the right formula and then they substitute

Researcher: Just to see what they have

Teacher: to see what they are given and not given.

29:28 – *the importance of activities for them to do, does it make them understand this topic better better, (how) does it help them*?

Teacher: It helps them for practice and then to see if at that instant they understand and if they do not understand then maybe you can go back or for them to see themselves if they are following on what the teacher is doing and also for me to see if they are able to do it. If they did it then…

Researcher: so activities should help them

Teacher: yes.

01:10 – *any problem on the work given. You checked the books to see if everyone did the work or?*

Teacher: I was checking if they all did it.

Researcher: In a case where one did not do it then…?

Teacher: If there is few who did not do it, then I ignore and continue with the lesson they will catch up during the lesson but if they are many then I have to stop give them another chance, checking what is the cause maybe sometimes you will find that they did not do it because they did not understand. If they are many you must find a reason why they did not write then I would see if it laziness or what.

02:55 – *why was it necessary to look at this activity with learners? Do you think it would have worked to have few learners writing their solutions on the board. Why or why not*?

Teacher: Yes for feedback so that individual learners can see if they had written correct information.

Researcher: In the process of doing it, would it work if you were to have few learners (2 or 3) writing their answers on the board on how they did the activity?

Teacher: It works but the thing is you will find that…according to policies, they state that maybe if there is homework, you must give 3 questions for homework but three would not do anything because if you can give learners three questions it encourages laziness. So seeing that if you give three they can see what want them to see if you have picked the questions properly but it makes them to be lazy. Then happens only to find that you give more, for the policy…definitely to test learners you can rotate them in doing solving the problems and see how they do it. But I am not sure if that is the aim of the policy but the work focussed on would be little and also you see this topic maybe you find that it has been given three hours of which is three days. Then you cannot do this in three days and learners understand it. Now considering that they say 3 days, they would not understand it and then we end up giving them work so that it would be quick and be able to cover the work because here what is expected is that you introduce another lesson. When you come in (to the class) you should do the lesson of the day so to introduce another lesson maybe see that when I have given them calculations (task) I can cover it in 30 minutes. And then I do the lesson of the day, all over again.

Researcher: so you start with corrections and then the lesson of the day

Teacher: yes, yes! I start with corrections and then the lesson of the day

05:55 – *resistance according to the exam guideline. Do they all have it? Is it different from the textbook that learners use? Its role?*

Teacher: yes they all have it.

Researcher: Does it have definitions only?

Teacher: It has definitions, it‘s like, it has all the definitions and then they must know them exactly the same as written in the guideline. Which means everything that is going to be asked during the exam is here (exam guideline) it‘s a scope. Even what you have to teach, you can but you should not move away from the exam guideline so that they (learners) will know that at this Grade (10) this is what we are doing.

Researcher: The definitions on the guideline, are they different from those found in the textbooks?

Teacher: Yes they are different. They should not follow textbooks a lot. For definitions, all of them they must be as per the exam guideline. The ones in the textbook even from my textbook that I use, they do not take it (definition). They must take the one that is there in the guideline because if its not the one, definition is required as is, word to word. If it‘s not word to word, its zero, two or zero.

09:50 – *some learners say 3; 0.5. why do you think it was the case*?

Teacher: They are looking at the other way round and the thing is I am not sure maybe it might happen that the way they had manipulated the formula, they did it vice versa. So it can happen that they are mentioning the answer that they have written down not looking at what I say and what is on the board also.

Researcher: Does this one help though? Giving this table of Ohm's Law

Teacher: Ehhhhh yes sometimes but the guideline says they must copy the formula from the data sheet so they do not manipulate formulas so that one (table) helps them when they are doing substitution for them to know that if they did not cross multiply and then they can easily arrive at the answer. Yeah its sad.

Researcher: Ok I hear you

Teacher: as for this only but with other things it just needs them to manipulate and then transpose.

14:00 – *speak of series resistors as being the same as series circuits… ……… what is it called actually (note for the researcher*)

Teacher: Yes

15:06 – *reason for cells of a torch example?*

Teacher: Something that they usually see (familiar with) that we put torch batteries following each other, then they are series.

Researcher: Ok so it was an example to make them understand series?

Teacher: Because in Grade 9 something that they deal with the most it is the batteries, cells then calculation of cells not considering series resistors. Their circuit is one with only a resistor, ammeter and voltmeter but mostly calculation of series, series and parallel are considered in cells in Grade 9.

18:26 – *strategy of using an arrow for parallel and series circuits to indicate the flow if current. How should this help learners*?

**Using no textbook to talk about all these things, is it the teaching experience helping you or you enjoy this section of electricity and magnetism (physical science)*?

Teacher: The emphasis of the arrow is to see…because when they have drawn the circuits, they (examiners) draw them learner get confused not seeing where is parallel and where is series. Even though individuals should consider their…we say there are in series but series to what? They are series to itself but also if it one (resistor) you will say series to what but they must refer to the cell then their series to be traced from the cell then their parallel also to be traced from the cell. Yes it helps because they can see now if the current is moving straight that means it is series and then if it splits and also because it is also important for them to know that series resistors do not divide current but divide potential difference and when in parallel they do not divide the … but current is divided. So something that you can easily trace is current, potential difference its not easy.

Researcher: and I see that when all these were happening you did not have even a textbook. Is it the teaching experience helping or you just enjoy the topic?

Teacher: It's experience and that I also relate with the topic as I did electricity in my engineering studies so yes yes.

27:45 – *finished the series, now its parallel. Does it make it a bit simpler to teach/introduce these separately*?

Teacher: If they are able to compare because they are two, see the similarities and the differences because in the final (exams) they (examiners) look for a combination. Combination of series as well as combination of parallel, so most of the asked questions are a combination, two parallel and one series. So if the learner was able to see that if they are in parallel they are like this, this is what is happening when they are in parallel and then if it is series, just to see the differences.

Researcher: Ok, why starting with the series and then parallel?

Teacher: This one (series) is simple and then parallel are challenging

06:05 – *why minimize it with one big resistor?*

**is this section mostly calculations?*

**why used equal resistors*?

Teacher: working out this (circuit) at the end, the circuit that they know from Grade 9 it had one resistor so which means whatever they do they must move up until they get to one resistor of which is total resistance.

Researcher: So it helps them in that sense?

Teacher: Yes it helps because which means if they are given scattered they must try to make it small because when it is scattered it is not easy to do calculations.

Researcher: I realised you did mostly calculations on this section, is it dominated bycalculations?

Teacher: Not exactly but the questions that will be asked from the theory part will ask them to calculate things. So they must prove what they have calculated but major marks are from calculations.

Researcher: Ok. So does using equal resistors helps them with voltage calculations?

Teacher: Yes. As we said here (series) that it splits potential difference so they must see that… (disturbed) like these ones they are going to share potential difference

00:55 – *why do you want them to start with the complex resistors*?

Teacher: From more complex to the simplest one because I said, at the end this is the one (simple circuit) they know so they must move from the complex to the simple.

Researcher: Ok I see. Thank you for your time sir, really appreciated!

……………………….……The end of the interview……….………………….

Appendix 10: Interview Schedule

Introductory questions:

1) Where did you attend your primary and secondary schools?
2) Where did you train to be a teacher (if trained to be a teacher)?
3) When did you train to be a teacher?
4) What were your subjects of specialization in your teacher training?
5) How long have you been teaching physical science?
6) What other subjects are you currently teaching? Any other duties in the school?

Research Interview Questions

1. What challenges, if any, do you experience while teaching physical science in grade 10?
2. With respect to your area, what difficulties, if any, does teaching physical science through has on your teaching and on learners understanding of scientific concepts?
3. Do you think learners have difficulties in understanding electricity and magnetism related concepts? If yes, which section is more challenging in electricity and magnetism?
4. What teaching strategies do you usually use when teaching physical science, specifically electricity and magnetism?
5. Do you use any form of representations when teaching electricity and magnetism? What type of representations do you often use?
6. Does the use of representations help your learners understand the content? If yes, how?
7. When teaching electricity and magnetism, what content (concepts) do you consider most important?
8. Have you observed any kind of misconceptions that your learners bring in class as you teach electricity and magnetism and/or during assessment of the topic?
9. Does the language of science specific to electricity and magnetism cause any difficulties or misunderstanding to your learners?
10. Which other languages do you use to emphasize or enhance the process of learning?
11. From your practice (experience), do you think it is advisable for a teacher to use general English language to explain electricity and magnetism concepts?

Thank you for your time and voluntary participation in this interview

Appendix 11: Sample of Semi-structured interview transcript with teacher Thando

Researcher: I would like to a talk to you to understand who you are, where you come from and how you do the things you do, can I please also record all that?

Teacher: I have no problem with that.

Researcher: Thank you so much. So I have a few questions to ask you like, where did you complete your secondary education?

Teacher: At Ohlanya High School in Enanda.

Researcher: Ohlanya High in Enanda.

Teacher: Yes.

Researcher: Which side?

Teacher: Durban.

Researcher: Oh okay.

Teacher: Ohlanya Institution.

Researcher: And when was it Ma'am? If you still remember.

Teacher: Uhm, I was there from 1986 to 1989.

Researcher: 1989 okay and to be a teacher where did you train?

Teacher: Indumiso College of Education.

Researcher: Where is it?

Teacher: Pietermaritzburg, Indumiso.

Researcher: Oh Indumiso.

Teacher: Yes and that was from 1993 to 1995.

Researcher: 1993 to 1995, okay.

Teacher: Yes then from 2003 to 2005 I went to H. Wood Campus in KZN. I was majoring my qualifications in Science there.

Researcher: Initially, what did you major with?

Teacher: With Physics but at an intermediate level.

Researcher: Alright.

Teacher: So I did an advance certificate in Physical Science teaching in KZN.

Researcher: But still you specialize in Physical Science?

Teacher: In Physics and Chemistry.

Researcher: That‘s nice. How long have you been teaching Physical Science?

Teacher: I started teaching in 1996 to date.

Researcher: Oh wow.

Teacher: Till today.

Researcher: It‘s quite a while hey!

Teacher: It‘s been 23… actually I started in 1992 but at that time I wasn‘t qualified so I taught for a year then went to college in 1993. So I was a privately paid teacher, we called that PPTA at first.

Researcher: Oh PPTA?

Teacher: So I was there for a year then the following year I was lucky enough to be accepted into the college then I studied and became qualified in 1996. That‘s when I started working.

Researcher: That‘s nice and you‘ve been here ever since or?

Teacher
In 1996 to 2006 I was in Ophongolo High School in Ncutshani doing Physical Science from grade 10 to 12 then I worked as a Head of Department of Scientist in Mnokotho High School from 2007 to 2012. I got married and relocated so I ended up teaching here.

Researcher: Okay and here which other subjects do you teach here?

Teacher: Natural Science.

Researcher : Grade?

Teacher: Grade 8. Sometimes I do teach grade 9 but not this year. I‘m just a specialist teaching Physical Science from grade 10 to 12. Although I teach the lower grades, I specialize in Physical Science but I also majored in Biology which is Life Sciences but I‘ve never received the opportunity to teach it. The last time I taught Biology was in 2000 so I‘ve never gotten the chance to teach the subject since then so I ended up specializing in Physics and Chemistry. This is what I do for a living.

Researcher: Yes, eish I see and here at school do you have other duties and responsibilities, besides teaching that you do?

Teacher: A teacher does not have one responsibility in a school, in general. We will never have one.

Researcher: Involving the school management?

Teacher: Partly yes, has a senior teacher they will use you but I am involved in uniform like the matric jackets and so on. I am also involved in netball, culture, SGB, unions and SCO as I am a born again Christian. I preach and do prayers.

Researcher: Okay then ma‘am. Coming to the teaching, how do you teach electricity and magnetism? If someone who didn‘t belong to this class where to walk in this class, like myself maybe for example and asked you how do you teach Electricity and Magnetism, what would you say to them?

Teacher: Uhm, fortunately for me I have a lab. Most schools around here do not have a lab and I am not talking about the kits but the laboratory itself. I am fortunate to have one and kits which were bought for me so I consider myself lucky. So as much as the time and space hinder us from doing a lot of practical work that we could do if the cases were different because one of the things that disturb us is that our children are collected from afar in remote areas to this school by buses and when the school is over for the day, they have to be taken back home by buses so it is not easy to have extra classes with those learners. So Practical work always needs an extra class but for us we have to steal minutes from our teaching time to do practicals which is not part of our allocated time as per ATP (Annual Teaching Plan) that is the problem but I try by all means to make sure that whatever that I talk about I show them. When I teach, especially magnetism, I show them the magnet, patterns and stuff like that as long as I can get a few, doesn‘t matter how tiny that particular thing is to me or when I look at it but I know that when a child looks at it, it has a difference then when I do it orally or as a theory only so I do give practical work except for the fact that we are overcrowded.

Researcher: What reasoning do you have to show them stuff no matter how small it is?

Teacher: ―Tell me, I‘ll forget. Show me, I‘ll remember‖ but the third is saying ―Involve me and I will understand.‖ But since there are 85 learners, if I can involve each and every one them it will be havoc so let me just make them remember what they see so I‘ll go to the ‗remember route‘ because the involvement part, ooooooh. I will find this lab in flames because they are so naughty but when I get a chance because in grade 12 they are 46 and I can see them after hours because they have forced extra classes so with them, I make them touch and involve them. It‘s also the same during class hours since they are also 46 its better instead of 85 in one class.

Researcher: And so far have you had any challenges with teaching Electricity and Magnetism? Any challenges?

Teacher: I don‘t have challenges except control.

Researcher: Yes classroom control?

Teacher: Class… Uh no I don‘t have challenges with that also but then the challenge of overcrowding but they say you can‘t teach a child because they are many in a class because it‘s only going to get worse. There are many children that are given birth to but there will be no schools built so they are 85 this year, next year they will be 105 so there is no way you can say you can‘t teach because they will be more the following year and from the time I started teaching here in 2012, I‘ve noticed an increase in numbers but the school isn‘t increasing in classes. They have tried though by putting prefabricated classes, these ones. But no teachers have been added.

Researcher: They‘re adding classes but no teachers.

Teacher: They‘re adding classes and adding children but no teachers so it means it‘s not helping.

Researcher: Mhmhmhm yes.

Teacher: That‘s a challenge. That‘s the main challenge but for what it‘s worth we are trying our best.

Researcher: Trying your best, yes it is a challenge. So what do you enjoy the most about teaching electricity and magnetism?

Teacher: Mhm children like it, it is better than when we talk about electrons basically it‘s better than Chemistry. Funny enough, I love Chemistry and I would love for my children to love it just like I do but they prefer electricity because most of the grade 10 learners want to be electrical engineers so 90% of them…

Researcher: So that‘s why.

Teacher: Yes so that‘s why they love it. You see when it comes to electricity you can see that their eyes lighten up. That‘s what I like about Electricity and Magnetism, they like it, they love it!

Researcher: Is it maybe the influence of the area?

Teacher: I don‘t know! I wouldn‘t say it‘s this area because from the time I started, I think they have this special thing about electricity. They just want to know how it works. They want to know all about electricity when they grow up so when they get the time to learn about it, hey they want to know. They think by knowing the word _resistor‘ they can go home and do tubing,

Researcher: *(Laughs)*

Teacher: I was telling them in front of you this particular time that do you think that *when you get home you‘ll just get and tell people to bring wires, globes, and bring everything*. They love it! They love electricity especially the girls I don‘t know why.

Researcher: That‘s quite interesting.

Teacher: What has interested me over the years is why do they love it? Even the electricity problems, they will struggle but come next week Friday you will see how they have tackled the electricity problems. Maybe they will have a challenge with the 1st or 2nd problem but from the 3rd, 4th, 5th hey you will see because it‘s something they like.

Researcher: It‘s something they love.

Teacher: They try hard when it comes to it.

Researcher: Yes.

Teacher: They are passionate. I don‘t know maybe they all want to be electrical engineers.

Researcher: Mhm yeah.

Teacher: I don‘t know how I can produce so many electrical engineers.

Researcher: Yes. Ma‘am with your experience from over the years, are there any specific difficulties that you have experienced that your learners have? Especially with Electricity and Magnetism.

Teacher: Mhmm.

Researcher: Some difficulties with when they have to learn the topic or write about the topic.

Teacher: Grade 10 usually now… because grade 10 is only the introduction, so it talks about the poles, the patterns, about the poles‘ attraction, nothing much when it comes to grade 10 but when they go to grade 11 that‘s where it becomes harder. Electricity and magnetism in grade 11 involves a lot of things and it becomes challenging and start seeing them refraining on magnetism only but if it‘s electricity, they don‘t lose their love for it.

Researcher: Oh yes, we don‘t know what‘s up.

Teacher: I also don‘t know what it is with the electricity, the series, the parallel and stuff.

Researcher: They like it.

Teacher: I‘ve never had a child who was struggling, even now in grade 12, struggling in circuits? No. Maybe I teach it differently because I like it. Even when we combine with other schools, they give me the electricity topic because maybe I explain it the other way.

Researcher: Wow that‘s nice.

Teacher: I can see my children are doing well in circuits but I‘m still going to give them a lot of these practices and then they will be okay. They will be okay. They are fine with the circuits because of the way I teach maybe. You see when a teacher likes that part, they teach it better.

Researcher: Exactly.

Teacher: Yes. In grade 12 give electric dynamics, I'll never touch it, I'll ask someone to teach it for me because I hate it! *(Laughs)*

Researcher: *(Laughs)*

Teacher: Motors and generators? No way do not I like it. I don't like that. I wouldn't even expect children to do well in it because I don't like it but I do teach it because I don't have a choice. But when I do, I get someone else to teach it for me.

Researcher: To come teach it for you.

Teacher: So you see, it is better that way.

Researcher: Oh wow.

Teacher: Because there is someone who likes it.

Researcher: Yeah.

Teacher: Someone who doesn't like teaching electricity calls me and I go to them.

Researcher : And then you teach it for them?

Teacher: Yes, I teach it for them. It's better like that.

Researcher : But which important concepts do you consider under Electricity and Magnetism that your kids do know?

Teacher: The thing about Electricity and Magnetism is that you study. You just lay a great foundation in grade 10 then they will be good in grade 12 when answering questions in their exam paper. The concepts that you have to install, actually the flow of charge, which is very important, versus the flow of electrons.

Researcher : Okay.

Teacher: Because if you say electricity flow of charge, they will always think from positive the electricity is always moving. The direction of electricity and conventional current must be emphasized in grade 10 because if you don't, you'll have problems in grade 11. The only thing that goes up are the levels when they introduce the internal resistance in grade 12. Otherwise if they had a good foundation in grade 10 it will be smooth sailing in grade 11 and 12. Yes.

Researcher : Oh okay but with what has happened so far from either last year or this year, have you seen misconceptions that your learners have regarding Electricity and Magnetism?

Teacher: Not.

Researcher : Not really?

Teacher : A lot!

Researcher : Oh a lot! Okay.

Teacher: A lot of misconceptions.

Researcher : Like?

Teacher: What I usually tell people is that I‘m also a class coordinator so what I usually tell them is that whenever you make examples, do not use things that no longer make sense. You see, growing up we say positive and positive repel like a boy and a boy, never use a boy and boy and girl and girl stuff because that misconception will confuse a child when it comes to people who live their lives as gays and lesbians. Refrain from that. There‘s this thing with explaining charges, its paper 1 but we use paper 2 to explain it because we are talking about the excess electrons and shortage of electrons when you are explaining positive/negative but it‘s in paper 2 and this one is in paper 1, so we have to create a boundary for them to see that is why we have charges but it‘s from paper 2 because it‘s a link between paper 1, Chemistry and Physics.

Researcher : Alright.

Teacher: Another misconception they tend to have is flow. They think it‘s electrons that move from positive to, the flow of charge, they think its electrons that are moving. Again, the electricity flow of charge we think it‘s just positive charges that are moving from positive to negative.

Researcher : From conventional current.

Teacher : From conventional current and you have to state that from the positive part it‘s the current that is moving but from the negative terminal there is movement but of electrons because you cannot have protons when there is excess of electrons. If that thing was not taught in grade 10, you‘ll still struggle with it in grade 12.

Researcher : Yes, I see.

Teacher: And it is best if you, as a teacher, to teach them from grade 10 and level up with them to 11 with the modules and further to grade 12 it‘s better that you because you get to up their game because they know how much you taught them, what you didn‘t say because some people introduced internal resistance in grade 11 but it‘s for grade 12. Although it does help them when starting it in grade 11 only if you will be the one teaching them in grade 12 then it will be alright.

Researcher : You‘ll be alright?

Teacher: Yes. So whatever the misconception is, the bad thing is when you take children who have been taught by someone else because you don‘t know what they have said.

Researcher : Eish yes. Like you in grade 12.

Teacher: I‘m in grade 12…

Researcher : 10 and 12.

Teacher: And someone who is teaching in grade 10 and 11 and I only get them in grade 12 then there‘s nothing much you can do with those children when they fail Physical Science. The best thing you can do for learners in Physical Science and Maths is to get to know them better and for them to know you so there aren‘t any surprises in grade 12.
They must know a teacher from grade 10, 11 or at least if the circumstances do not allow, at least let them get a teacher in grade 11 to go up with to grade 12.

Researcher : Grade 12.

Teacher: Not when you go to grade 12 and find a new educator. They don‘t even know what to expect and you see it‘s…

Researcher : Quite a challenge.

Teacher: It‘s a challenge when you do it like that.

Researcher : Mhm okay, so how do you help the learners understand the concepts that you are dealing with in electricity and magnetism?

Teacher: Eh! You see sometimes you can give them extra work but they don‘t do it. You want them to do the extra work but time doesn‘t allow because we have 5 periods out of 6 and the free periods you just want to sleep.

Researcher : *(Laughs)*

Teacher: So there are those challenges. Uh, I have got a little *[Inaudible 23:04]*, the more you give them activities, the more practice they have. The best thing is individual attention but it is impossible for us.

Researcher : It‘s impossible?

Teacher: Yes. If they were at least 40 in a class then we would have been able to do it like that. We want to help them but at times it‘s impossible. At the same time you end up making them responsible even by swearing at them saying, ―You don‘t want learn? You‘re going to fail‖ just threatening them about failing because you want them to do their part. Most of the time when you give the extra work, like I gave them more work for the weekend because I want to keep them busy but some of them won‘t do it you see, and it will be difficult for me to make sure everyone did their work, all 85 learners.

Researcher : Yes.

Teacher: We try, maybe what we do is give them extra work and so since they don‘t expect me to say ―The 3rd row bring my exercise books‖ you see I won‘t know who‘s going to bring my exercise books on that day. That‘s how I do it. I give them the extra and call on the back row to bring their exercise books and take those. The following day I call the front row and see if everyone is ready, then call the second row. If you do it like that then you will be able to catch those who didn‘t do their work since they least expect to be called.

Researcher : With the activities that you give them, do they all have textbooks?

Teacher: They all have textbooks.

Researcher : Individually?

Teacher : Individually and that‘s the only thing good about the school. This is why you do not see lots of notes because all of them have textbooks. If you do not have the other one, you‘ve got the other one.

Researcher : Mmm.

Teacher: But there‘s no one who doesn‘t have a textbook. They have Study and Master and if they do not have that one, they have the Platinum textbook, so everyone has one or the other.

Researcher : Mhm!

Teacher: So yes it‘s nice. That‘s the best thing about this school, they make sure everyone has books. Especially Maths and Science. Because they wanted to change it to a Science school. During trials a learner got 78% last year in grade 12.

Researcher : Physical Science?

Teacher: Yes.

Researcher : Wow.

Teacher: If he could have at least gotten 100 or 80.

Researcher : He got 78%. Wow! That‘s really amazing. Congratulations Ma‘am, that‘s really nice!

Teacher: Just great!

Researcher : The languages that you use, do you only use English or do you switch a bit to Zulu for them to understand?

Teacher: English across curriculum is a must which means you are forced as an educator to use English throughout.

Researcher : Yes.

Teacher: But usually you can see when they really don‘t understand then you can start stealing a little bit, not a lot. For me, 80% it‘s English then 20% I‘ll explain several things in

Zulu, here and there. When it moves from here then we have to explain it in Zulu because sometimes you can see that they really do not understand.

Researcher : They don‘t understand.

Teacher: Yes but it‘s just stealing for them in their language but according to the policy under the Department of Education says you must not switch.

Researcher : Just use English.

Teacher: Uh as much as we use English you say you have taught but if they don‘t understand who is being helped there?

Researcher : *(Sighs)* Ma‘am they‘re not assisting right?

Teacher: Yes they are not helping. They are not even helping themselves because if they make sure learners understand English very well in the first place, because you can‘t expect a child who cannot even express themselves in English to be taught completely in English without trying to explain otherwise they will not know Physics at all, when they are not even able to state the law then what can you say?

Researcher : Eish! It‘s the challenges.

Teacher: Its starts from the bottom, the basic. They don‘t know English.

Researcher : It‘s a problem.

Teacher: For those who went to multi-racial schools, you can see the difference. Even when they answer you, you can see they understand the question. Sometimes you can tell that the child knew whatever but could not understand the question because of the language barrier. There is a lot in question to language barrier and we don‘t know what we can do about it. That is why teachers in other subjects end up trying to teach it in Isizulu which is not right but there‘s not much we can...

Researcher : Do, I know. I know.

Teacher : I do it anyway. I do teach in English and explain a little bit in Zulu, only a little bit because when I visit the other school I never say anything in Zulu nor even try because…

Researcher : All is said in English.

Teacher: When they ask you a question in Zulu like ―May I ask if…‖ and you see that they understand the question but they still have to think it in Zulu and try to… it‘s dangerous. Once we talked about batteries, there‘s a syllabus that we used to have with capacitors, remember that one?

Researcher : Mhm.

Teacher: Yes I did that one so…

Researcher : We don‘t have capacitors anymore?

Teacher: No we don‘t do it anymore.

Researcher : Oh! Okay.

Teacher : So there were batteries there and they were explaining why a battery goes flat you see, then when the child explains in Zulu ―Then the battery dies.‖

Researcher : *(Laughs)*

Teacher: When a child tries to explain that they have to think back to English from Zulu, saying ―The battery is dead.‖

Researcher : It‘s dead.

Teacher: And can you guess what they say? ―The battery flies away.‖

Researcher : *(Laughs)*

Teacher: ―The battery disappears‖, ―The battery goes‖, ―The battery…‖ you see?

Researcher : Mhmmmm!

Teacher: You see? Because you said ‗*Iphelile*‘ the battery is finished, you say anything that comes to mind. Whatever that means ‗*Iphelile*‘ to their minds. Sometimes ‗*Uphelile*‘ is something else to them. ‗*Phelile ibattery, gone*‘ it flew away.

Researcher : It‘s gone!

Teacher: Yes it‘s disappeared.

Researcher : It‘s not here anymore.

Teacher: Yes, disappeared. Gone! It‘s no more. The battery is no more. Passed away! Really!

Researcher : Oh Ma‘am! Thank you so much, it was nice being here, in this school!

---------------------The end of the interview-----------------------

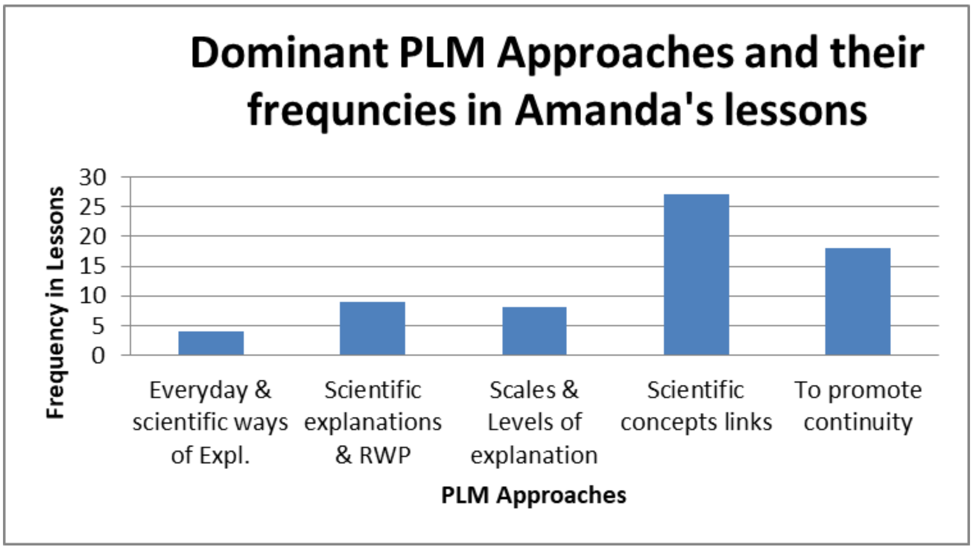
Appendix 12: Coding of teachers' lessons

Explanation of codes

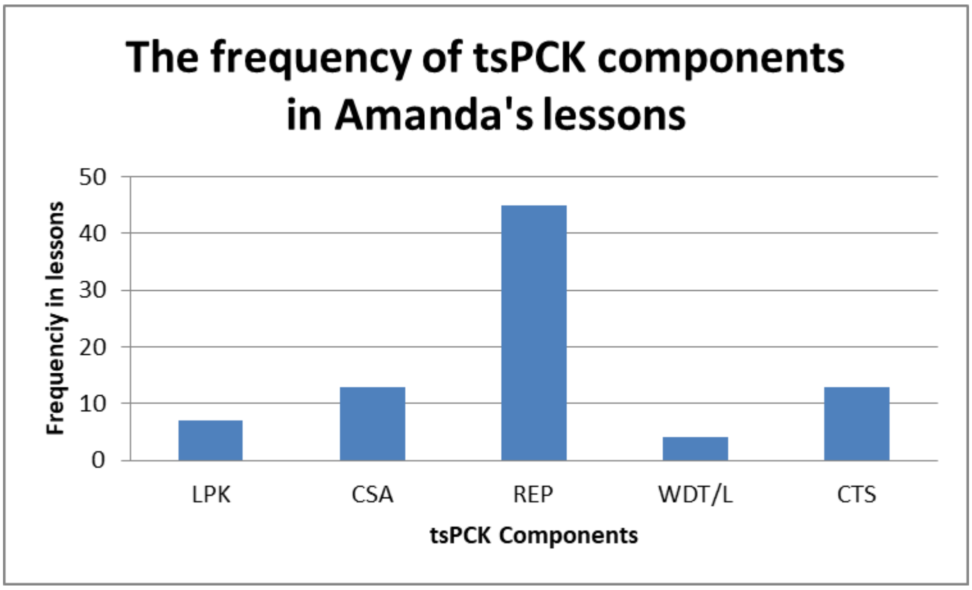
Codes	Definition
LES	Stands for link-making between everyday and scientific ways of explaining.
SERW	Refers to link-making between scientific explanations and real world phenomena.
SLE	Refers to link-making between different scales and levels of explanation.
SCT	Refers to making links between scientific concepts
CSS	Refers to link-making to promote continuity to develop a scientific story.
ANA	Refers to the analogical link-making.
LPK-Mis	Refers to addressing misconceptions within the learner prior knowledge category of tsPCK.
LPK-Pre	Refers to teacher‘s reference to knowledge that learners should have (pre-requisite knowledge), either from previous lessons, grades or from everyday experiences (learner prior knowledge).
CSA-Em	Refers to particular emphasis of scientific concepts or processes.
CSA-KC	Refers to teacher‘s understanding of knowledge in curriculum including sequencing of Big Ideas and subordinate ideas within the subject, theme, and topic.
CSA-RPre	Refers to teacher‘s reflection of pre-requisite knowledge through explanations
REP	Stands for representations
WDT/L	Refers to what teachers found difficult to teach including addressing those scientific concepts and processes considered difficult for learners to learn.
CLPK	Refers to teacher‘s confirmation of learners prior knowledge

Amanda's Lessons

Pedagogical Link-Making Approaches	Features / characteristics	Sub-concepts	Codes	Frequency			
				L1	L2	L3	TOTAL
To support knowledge building	Making links between everyday and scientific ways of explaining	Integration	LES – 1	1	-	-	**1**
		Differentiation	LES – 2	3	-	-	**3**
	making links between scientific explanations and real world phenomena	Concrete phenomena	SERW – 1	-	1	-	**1**
		Complex phenomena	SERW – 2	1	7	-	**8**
	Moving between different scales and levels of explanation	Sub-micro - macroscopic	SLE – MiMa	-	1	-	**1**
		Sub-microscopic - symbolic	SLE - MiSy	-	-	-	**-**
		Macro – sub-microscopic	SLE – MaMi	2	2	-	**4**
		Macroscopic – symbolic	SLE – MaSy	3	-	-	**3**
		Symbolic - macroscopic	SLE – SyMa	-	-	-	**-**
		Symbolic – sub-microscopic	SLE – SyMi	-	-	-	**-**
	Links between scientific concepts	Integration	SCT – 1	9	9	2	**20**
		Differentiation	SCT - 2	4	3	-	**7**
To promote continuity	Continuity to develop the scientific story	Macro scale	CSS – 1	6	-	-	**6**
		Meso scale	CSS – 2	7	1	1	**9**
		Micro scale	CSS – 3	1	1	1	**3**

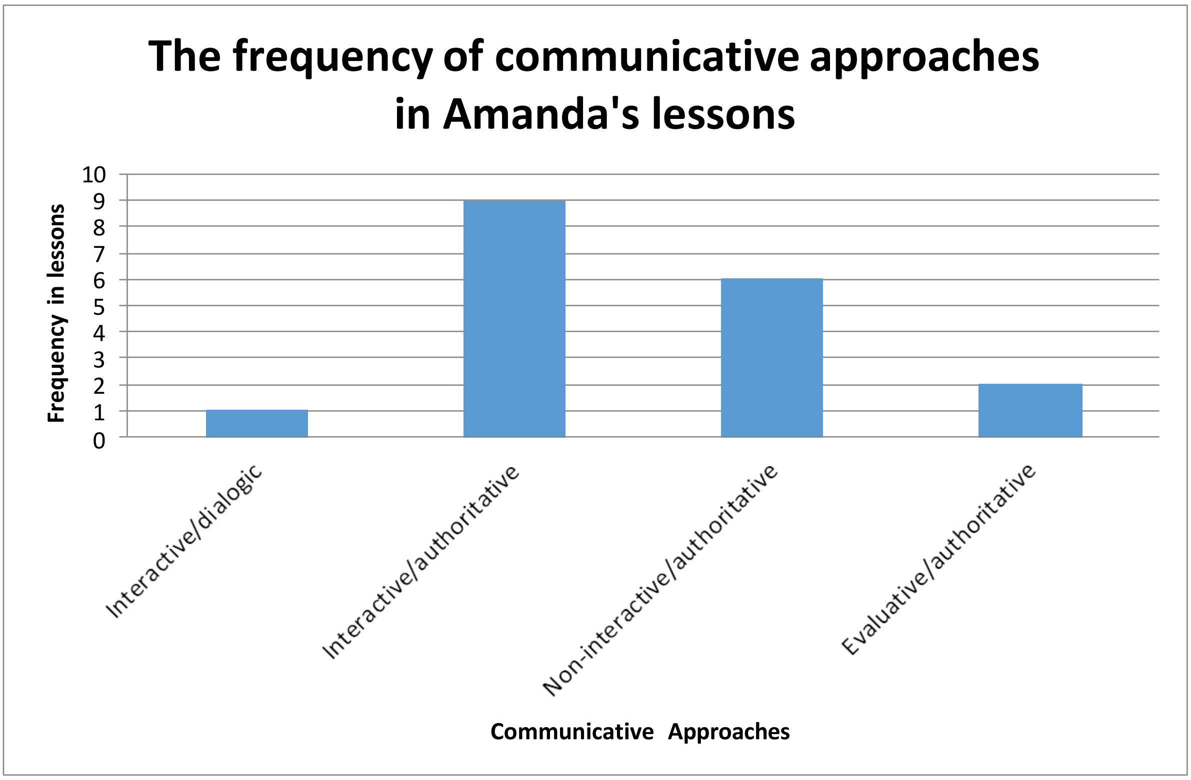


TsPCK components	**Features/characteristics**	**Codes**	**Frequency**			
			L1	L2	L3	**TOTAL**
Learner Prior Knowledge (LPK)	Addressing misconceptions	LPK - Mis	-	-	1	**1**
	Pre-requisite knowledge	LPK - Pre	1	2	3	**6**
Curricular saliency (CSA)	Knowledge in curriculum	CSA - KC	3	2	-	**5**
	Emphasis	CSA - Em	2	3	1	**6**
	Reflecting on pre-requisite knowledge	CSA - RPre	2	-	-	**2**
Representations (REP)	Sub-Microscopic	REP - 1	-	-	-	**-**
	Macroscopic	REP - 2	7	6	-	**13**
	Symbolic	REP - 3	11	14	7	**32**
What is difficult to teach or learn (WDT/L)	Difficult concepts/processes for teaching & learning	WDT/L - DTL	2	2	-	**4**
Conceptual teaching strategies (CTS)	Confirmation / confrontation of LPK	CLPK	7	6	-	**13**



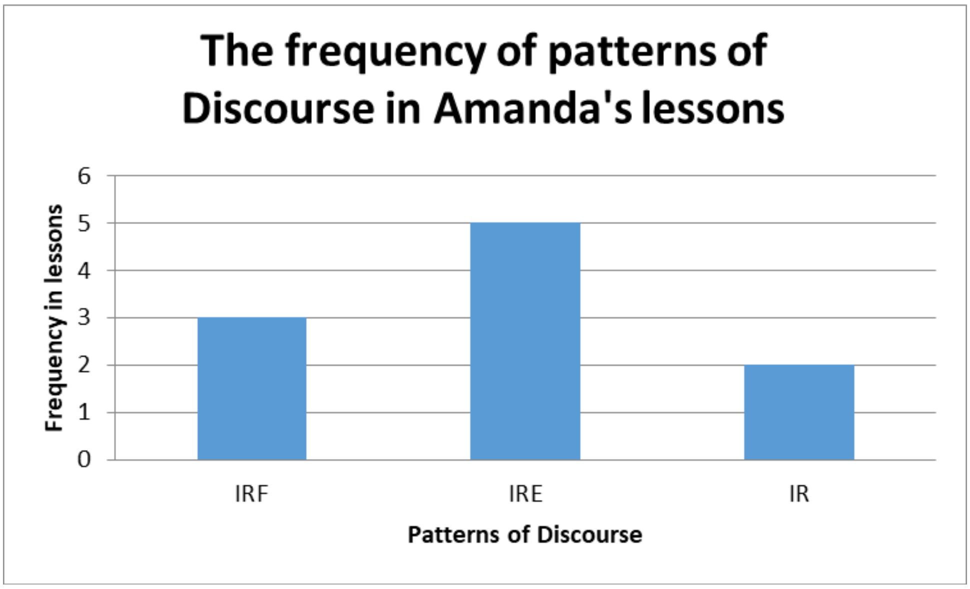
Communicative Approaches

Features/characteristics	Codes	Frequency			
		L1	**L2**	**L3**	**TOTAL**
Interactive/dialogic	Int-Di	1	-	-	**1**
Interactive/authoritative	Int-Au	3	3	3	**9**
Non-interactive/dialogic	Non-Di	-	-	-	**-**
Non-interactive/authoritative	Non-Au	1	1	4	**6**
Evaluative/authoritative	Eval-Au	2	-	-	**2**
Feedback/authoritative	Fb-Au	-	-	-	**-**



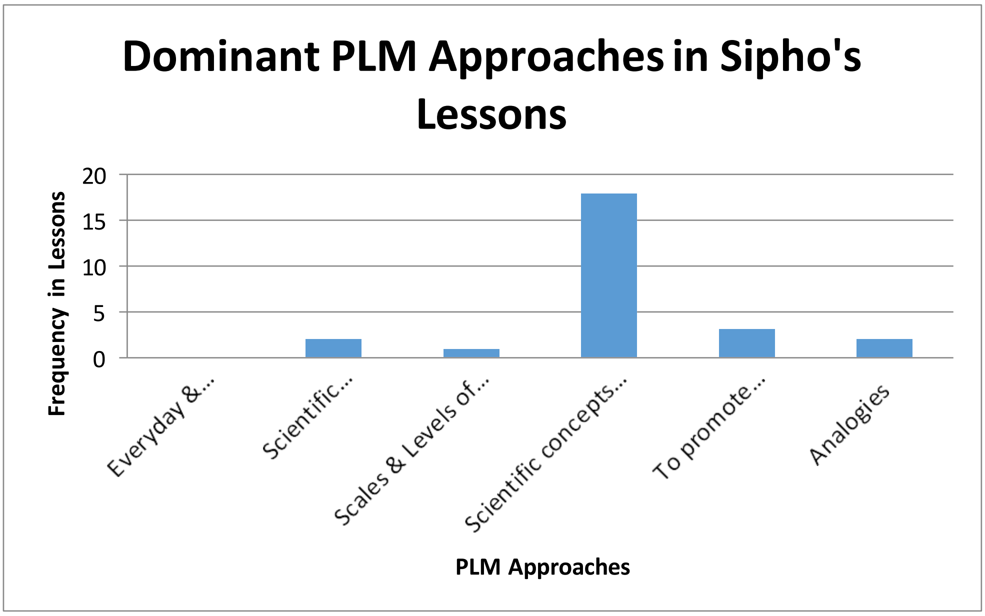
Patterns of Discourse

Features/characteristics	Codes	Frequency			
		L1	L2	L3	TOTAL
Initiation – Response – Feedback	IRF	6	3	1	**10**
Initiation – Response – Evaluation	IRE	2	4	1	**7**
Initiation – Response	IR	4	2	-	**6**

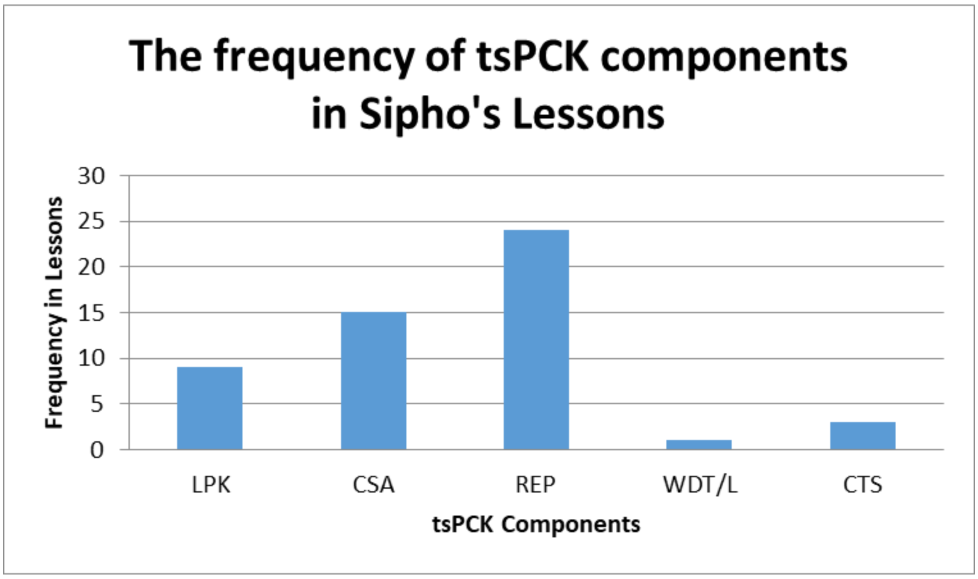

The frequency of patterns of Discourse in Amanda's lessons
Frequency in lessons
6
5
4
3
2
1
0
IRF
IRE
IR
Patterns of Discourse

Sipho's Lessons

Pedagogical Link-Making Approaches	Features / characteristics	Sub-concepts	Codes	Frequency			
				L1	L2	L3	TOTAL
To support knowledge building	Making links between everyday and scientific ways of explaining	Integration	LES – 1	-	-	-	**-**
		Differentiation	LES – 2	-	-	-	**-**
	making links between scientific explanations and real world phenomena	Concrete phenomena	SERW – 1	1	-	-	**1**
		Complex phenomena	SERW – 2	-	1	-	**1**
	Moving between different scales and levels of explanation	Sub-micro - macroscopic	SLE – MiMa	-	-	-	**-**
		Sub-microscopic - symbolic	SLE - MiSy	1	-	-	**1**
		Macro – sub-microscopic	SLE – MaMi	-	-	-	**-**
		Macroscopic – symbolic	SLE – MaSy	-	-	-	**-**
		Symbolic - macroscopic	SLE – SyMa	-	-	-	**-**
		Symbolic – sub-microscopic	SLE – SyMi	-	-	-	**-**
	Links between scientific concepts	Integration	SCT – 1	10	4	1	**15**
		Differentiation	SCT - 2	1	2	-	**3**
	Analogical link-making	Analogies	ANA	1	1	-	**2**
To promote continuity	Continuity to develop the scientific story	Macro scale	CSS – 1	2	-	-	**2**
		Meso scale	CSS – 2	-	-	-	**-**
		Micro scale	CSS – 3	-	-	1	**1**

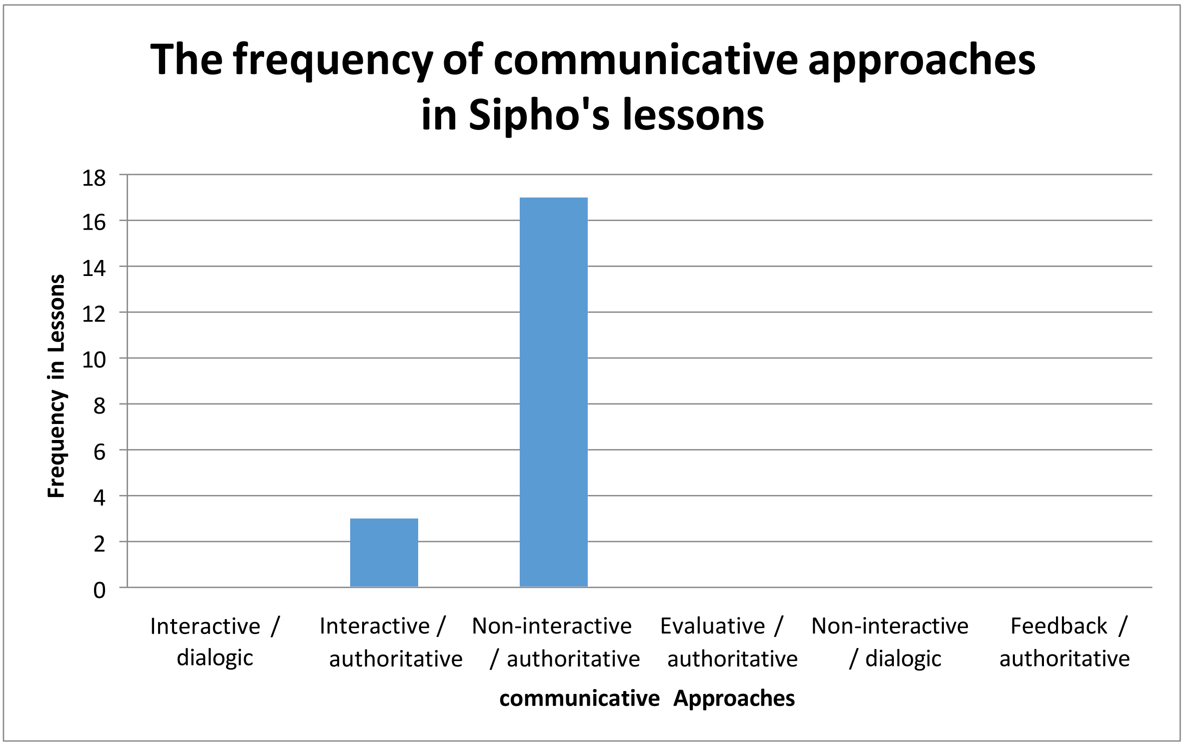


TsPCK components	Features/characteristics	Codes	Frequency			
			L1	L2	L3	TOTAL
Learner Prior Knowledge (LPK)	Addressing misconceptions	LPK - Mis	-	1	-	**1**
	Pre-requisite knowledge	LPK - Pre	7	1	-	**8**
Curricular saliency (CSA)	Knowledge in curriculum	CSA - KC	1	1	-	**3**
	Emphasis	CSA - Em	-	3	-	**3**
	Reflecting on pre-requisite knowledge	CSA - RPre	5	1	3	**9**
Representations (REP)	Sub-Microscopic	REP - 1	-	-	-	**-**
	Macroscopic	REP - 2	-	-	-	**-**
	Symbolic	REP - 3	8	11	5	**24**
What is difficult to teach or learn (WDT/L)	Difficult concepts/processes for teaching & learning	WDT/L - DTL	-	1	-	**1**
Conceptual teaching strategies (CTS)	Confirmation / confrontation of LPK	CLPK	3	-	-	**3**



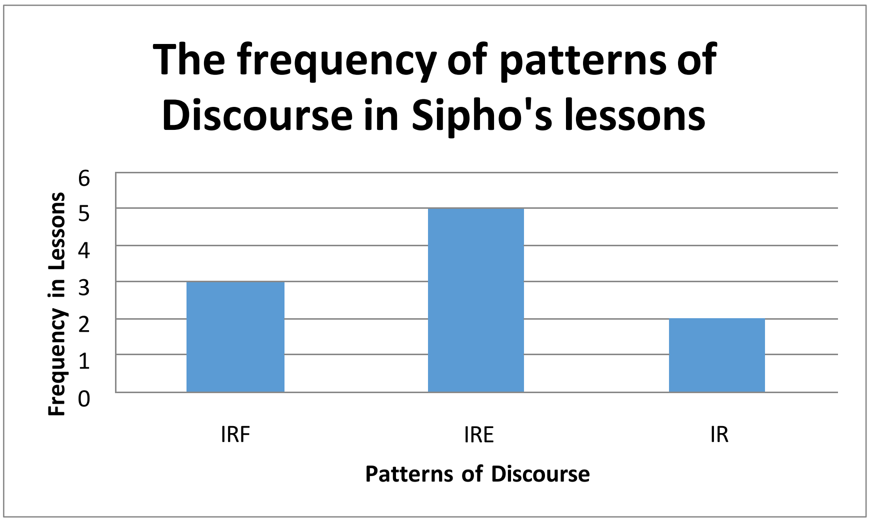
Communicative Approaches

Features/characteristics	Codes	Frequency			
		L1	L2	L3	TOTAL
Interactive/dialogic	Int-Di	-	-	-	**-**
Interactive/authoritative	Int-Au	3	-	-	**3**
Non-interactive/dialogic	Non-Di	-	-	-	**-**
Non-interactive/authoritative	Non-Au	8	7	2	**17**
Evaluative/authoritative	Eval-Au	-	-	-	**-**
Feedback/authoritative	Fb-Au	-	-	-	**-**


The frequency of communicative approaches in Sipho's lessons
Frequency in Lessons
0
2
4
6
8
10
12
14
16
18
Interactive / dialogic
Interactive / authoritative
Non-interactive / authoritative
Evaluative / authoritative
Non-interactive / dialogic
Feedback / authoritative
communicative Approaches

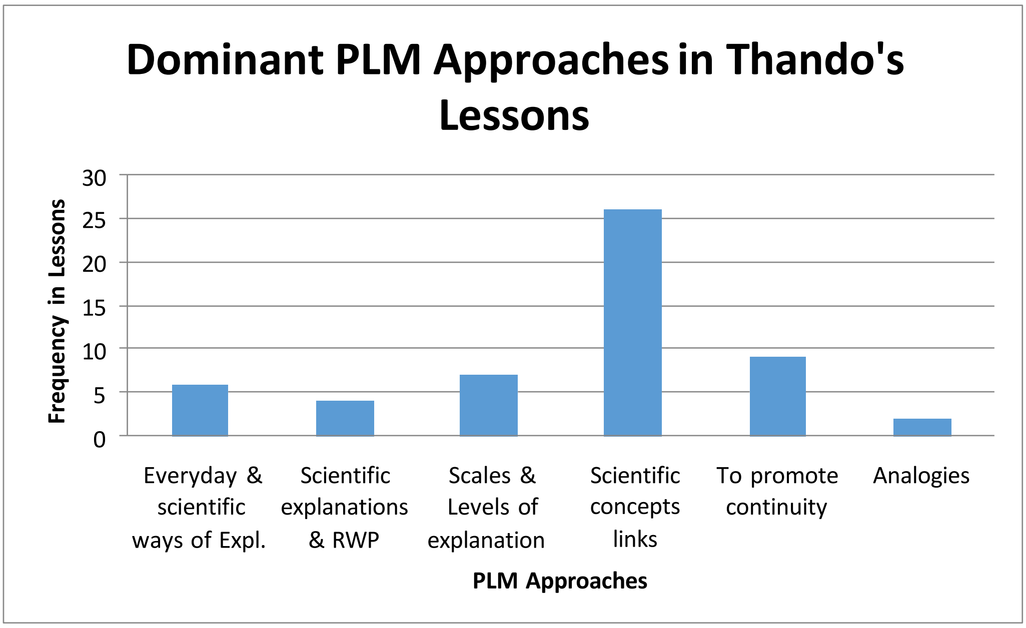
Patterns of Discourse

Features/characteristics	Codes	Frequency			
		L1	**L2**	**L3**	**TOTAL**
Initiation – Response – Feedback	IRF	2	1	-	**3**
Initiation – Response – Evaluation	IRE	5	-	-	**5**
Initiation – Response	IR	2	-	-	**2**

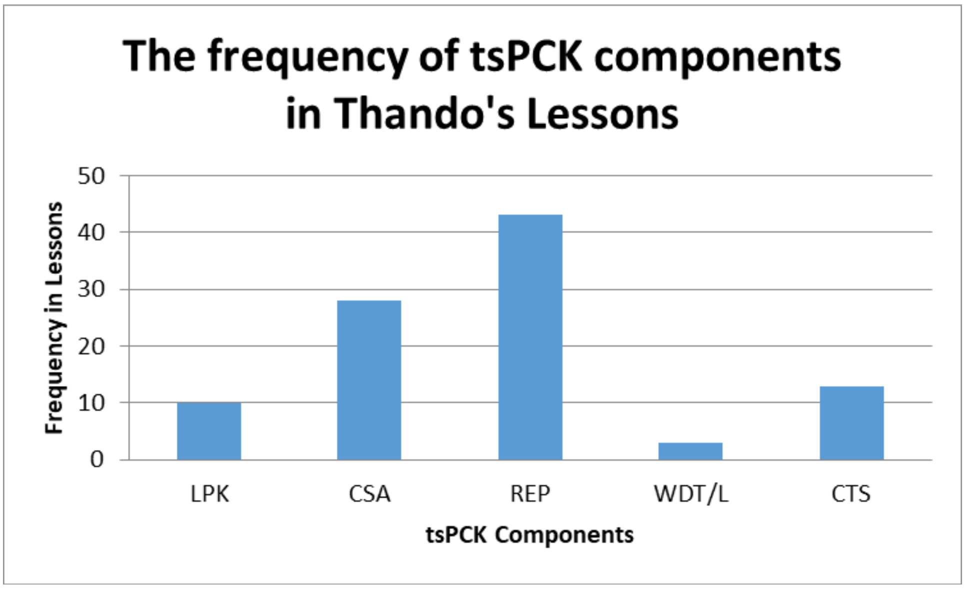


Thando's Lessons

Pedagogical Link-Making Approaches	Features / characteristics	Sub-concepts	Codes	Frequency				
				L1	L2	L3	L4	TOTAL
To support knowledge building	Making links between everyday and scientific ways of explaining	Integration	LES – 1	-	1	-	-	**1**
		Differentiation	LES – 2	2	2	1	-	**5**
	making links between scientific explanations and real world phenomena	Concrete phenomena	SERW – 1	2	-	-	-	**2**
		Complex phenomena	SERW – 2	1	-	1	-	**2**
	Moving between different scales and levels of explanation	Sub-micro - macroscopic	SLE – MiMa	-	1	-	-	**1**
		Sub-microscopic - symbolic	SLE - MiSy	-	-	-	-	**-**
		Macro – sub-microscopic	SLE – MaMi	2	1	-	-	**3**
		Macroscopic – symbolic	SLE – MaSy	-	-	-	-	**-**
		Symbolic - macroscopic	SLE – SyMa	1	-	-		**1**
		Symbolic – sub-microscopic	SLE – SyMi	1	-	1	-	**2**
	Links between scientific concepts	Integration	SCT – 1	3	5	3	-	**11**
		Differentiation	SCT - 2	4	3	8	-	**15**
	Analogical link-making	Analogies	ANA	2	-	-	-	**2**
To promote continuity	Continuity to develop the scientific story	Macro scale	CSS – 1	4	-	-	-	**4**
		Meso scale	CSS – 2	-	4	-	**1**	**5**
		Micro scale	CSS – 3	-	-	-	-	**-**

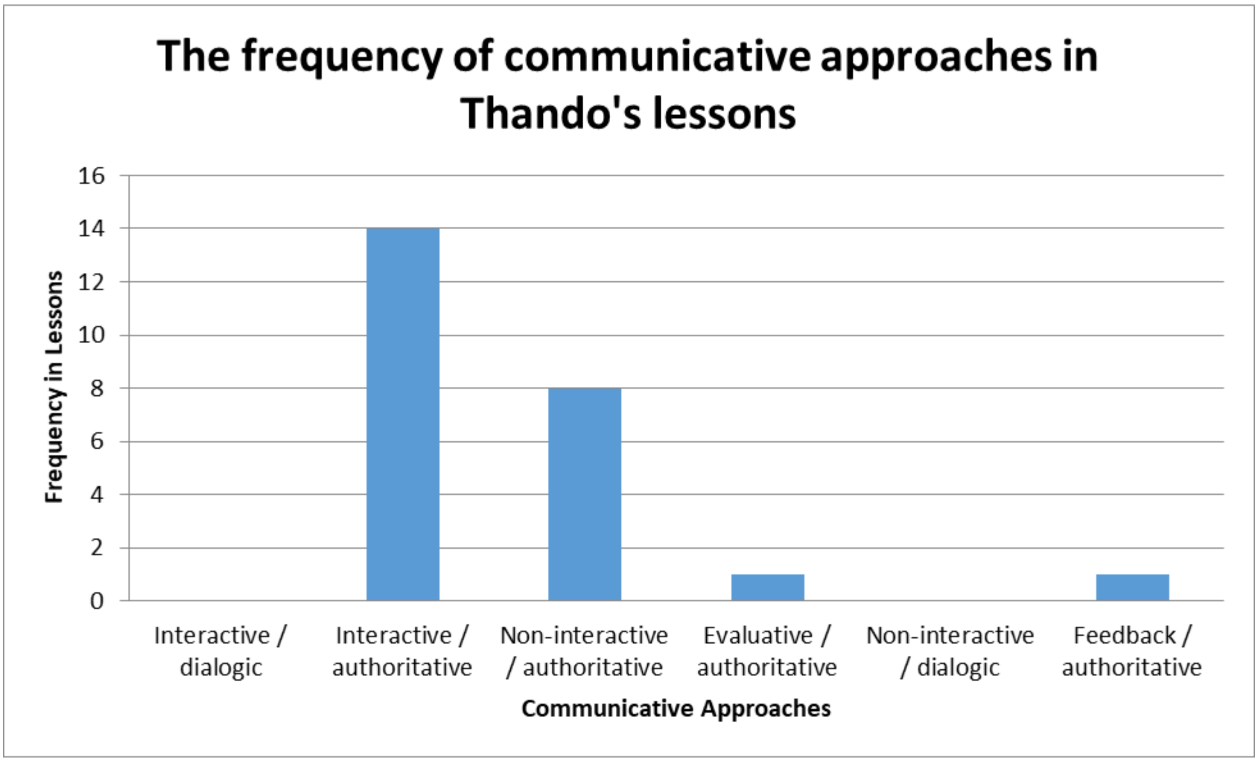


TsPCK components	Features/characteristics	Codes	Frequency				
			L1	L2	L3	L4	**TOTAL**
Learner Prior Knowledge (LPK)	Addressing misconceptions	LPK - Mis	1	-	-	**-**	**1**
	Pre-requisite knowledge	LPK - Pre	5	3	-	**1**	**9**
Curricular saliency (CSA)	Knowledge in curriculum	CSA - KC	2	2	2	**-**	**6**
	Emphasis	CSA - Em	4	3	5	**1**	**13**
	Reflecting on pre-requisite knowledge	CSA - RPre	5	3	-	**1**	**9**
Representations (REP)	Sub-Microscopic	REP - 1	-	-	-	**-**	**-**
	Macroscopic	REP - 2	1	6	-	**-**	**7**
	Symbolic	REP - 3	5	10	17	**4**	**36**
What is difficult to teach or learn (WDT/L)	Difficult concepts/processes for teaching & learning	WDT/L - DTL	3	-	-	**-**	**3**
Conceptual teaching strategies (CTS)	Confirmation / confrontation of LPK	CLPK	-	-	-	**-**	**13**



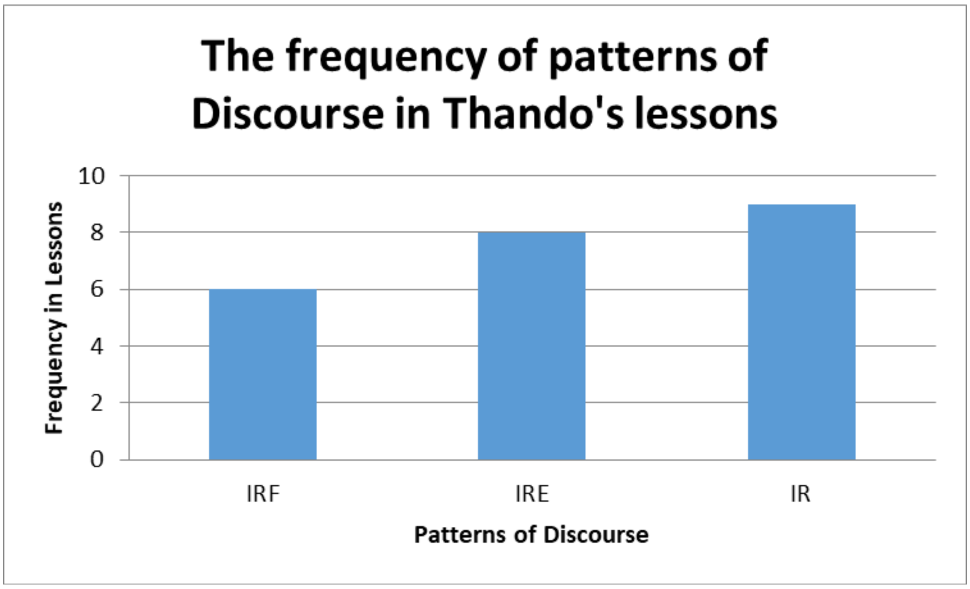
Communicative Approaches

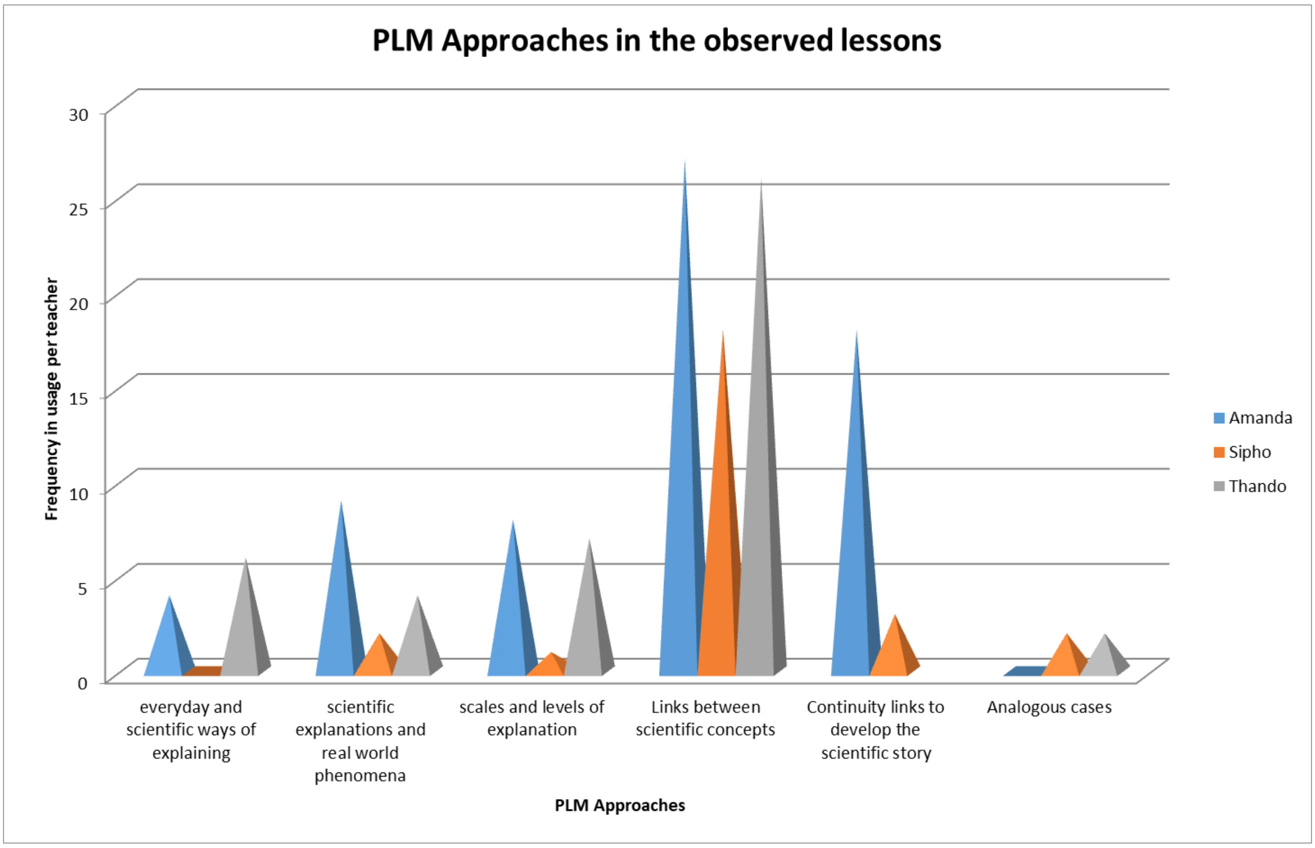
Features/characteristics	Codes	Frequency				
		L1	**L2**	**L3**	**L4**	**TOTAL**
Interactive/dialogic	Int-Di	-	-	-	-	-
Interactive/authoritative	Int-Au	4	7	3	-	**14**
Non-interactive/dialogic	Non-Di	-	-	-	-	-
Non-interactive/authoritative	Non-Au	4	1	3		**8**
Evaluative/authoritative	Eval-Au	-	1	-	-	**1**
Feedback/authoritative	Fb-Au	-	1	-	-	**1**

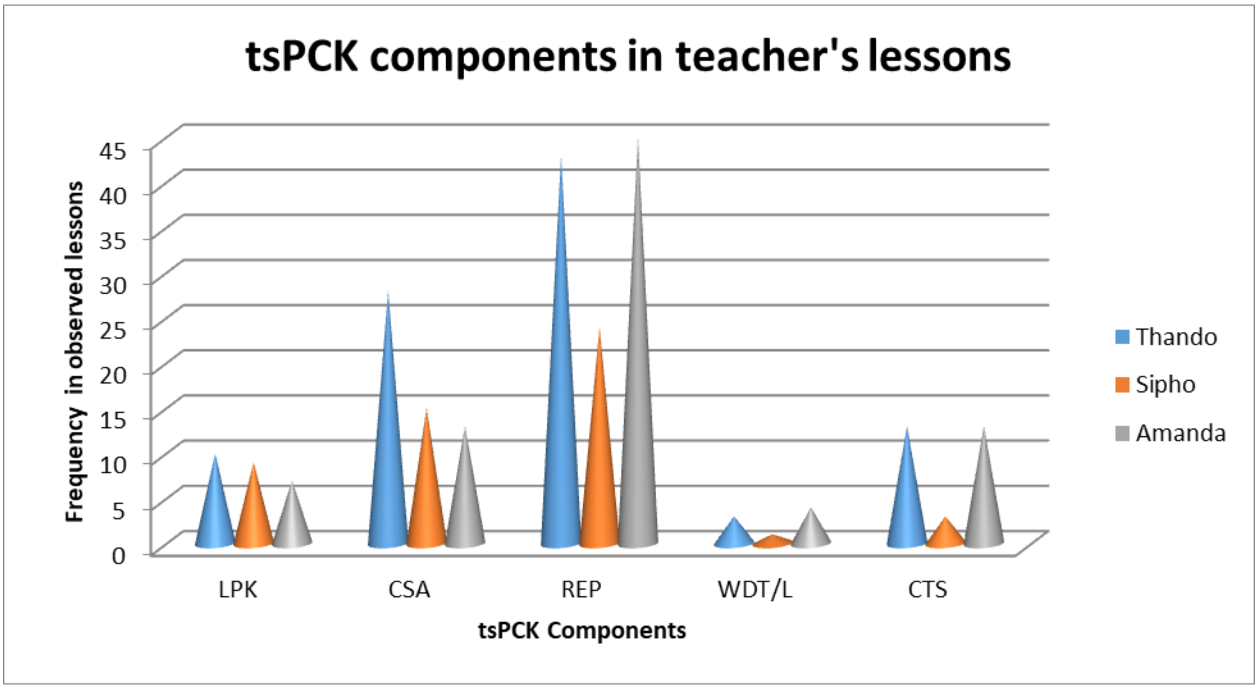


Patterns of Discourse

Features/characteristics	Codes	Frequency				
		L1	L2	L3	L4	TOTAL
Initiation – Response – Feedback	IRF	-	4	2	-	**6**
Initiation – Response – Evaluation	IRE	3	5	-	-	**8**
Initiation – Response	IR	3	2	1	3	**9**


The frequency of patterns of Discourse in Thando's lessons
Frequency in Lessons
10
8
6
4
2
0
IRF
IRE
IR
Patterns of Discourse

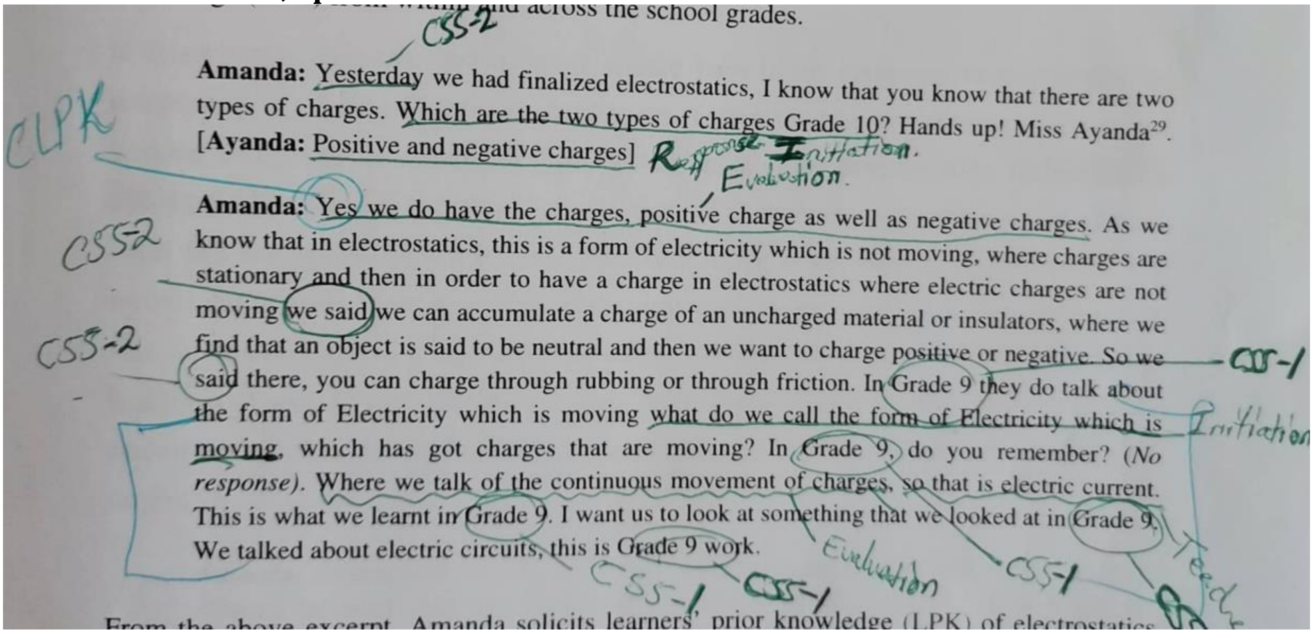

PLM Approaches in the observed lessons
Frequency in usage per teacher
30
25
20
15
10
5
0
Amanda
Sipho
Thando
everyday and scientific ways of explaining
scientific explanations and real world phenomena
scales and levels of explanation
Links between scientific concepts
Continuity links to develop the scientific story
Analogous cases
PLM Approaches



tsPCK components in teacher's lessons
Frequency in observed lessons
45
40
35
30
25
20
15
10
5
0
LPK
CSA
REP
WDT/L
CTS
tsPCK Components
Thando
Sipho
Amanda

Appendix 13: Samples of coded teacher observations

Amanda's Lesson 1, episode 1



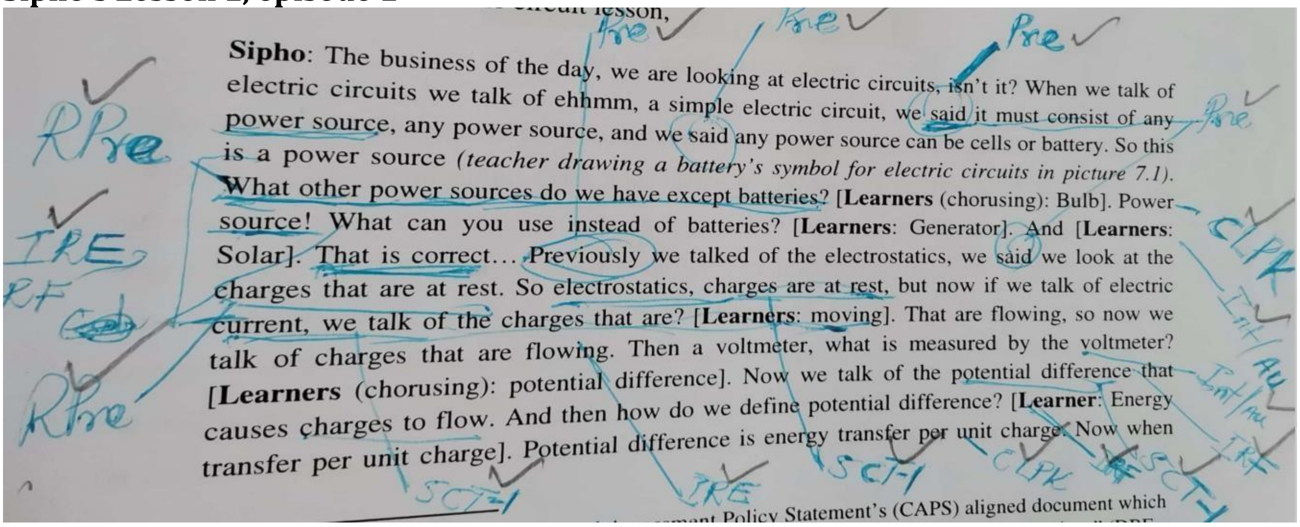
... from within and across the school grades.

Amanda: Yesterday we had finalized electrostatics, I know that you know that there are two types of charges. Which are the two types of charges Grade 10? Hands up! Miss Ayanda[29]. [**Ayanda:** Positive and negative charges]

Amanda: Yes we do have the charges, positive charge as well as negative charges. As we know that in electrostatics, this is a form of electricity which is not moving, where charges are stationary and then in order to have a charge in electrostatics where electric charges are not moving we said we can accumulate a charge of an uncharged material or insulators, where we find that an object is said to be neutral and then we want to charge positive or negative. So we said there, you can charge through rubbing or through friction. In Grade 9 they do talk about the form of Electricity which is moving what do we call the form of Electricity which is moving, which has got charges that are moving? In Grade 9, do you remember? *(No response)*. Where we talk of the continuous movement of charges, so that is electric current. This is what we learnt in Grade 9. I want us to look at something that we looked at in Grade 9. We talked about electric circuits, this is Grade 9 work.

From the above excerpt, Amanda solicits learners' prior knowledge (LPK) of electrostatics

Sipho's Lesson 1, episode 1



... circuit lesson,

Sipho: The business of the day, we are looking at electric circuits, isn't it? When we talk of electric circuits we talk of ehhmm, a simple electric circuit, we said it must consist of any power source, any power source, and we said any power source can be cells or battery. So this is a power source *(teacher drawing a battery's symbol for electric circuits in picture 7.1)*. What other power sources do we have except batteries? [**Learners** (chorusing): Bulb]. Power source! What can you use instead of batteries? [**Learners**: Generator]. And [**Learners**: Solar]. That is correct… Previously we talked of the electrostatics, we said we look at the charges that are at rest. So electrostatics, charges are at rest, but now if we talk of electric current, we talk of the charges that are? [**Learners**: moving]. That are flowing, so now we talk of charges that are flowing. Then a voltmeter, what is measured by the voltmeter? [**Learners** (chorusing): potential difference]. Now we talk of the potential difference that causes charges to flow. And then how do we define potential difference? [**Learner**: Energy transfer per unit charge]. Potential difference is energy transfer per unit charge. Now when

... Policy Statement's (CAPS) aligned document which

Appendix 14: Examination guideline

Exam Guidelines.

[redacted] [redacted]

basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

Grade 10

Physical Sciences Guidelines Document & Exemplar Papers

Earth's magnetic field, compass

- Explain how a compass indicates the direction of a magnetic field.
- Compare the magnetic field of the Earth to the magnetic field of a bar magnet.
- Explain the difference between the geographical North Pole and the magnetic north pole of the Earth.
  Geographic north pole: Point in the northern hemisphere where the rotation axis of the Earth meets the surface.
  Magnetic north pole: The point where the magnetic field lines of the Earth enters the Earth. It is the direction in which the north pole of a compass points.
  Magnetic south pole: The point where the magnetic field lines of the Earth leaves the Earth.
- Give examples of phenomena that are affected by Earth's magnetic field, e.g. Aurora Borealis (Northern Lights) and magnetic storms.
  Aurora Borealis (Northern Lights): An atmospheric phenomenon consisting of bands of light at the north pole caused by charged solar particles following the Earth's magnetic lines of force.
  Magnetic storm: A disturbance in the Earth's outer magnetosphere, usually caused by streams of charged particles given off by solar flares.
  Magnetosphere: A region surrounding the Earth (extending from about one hundred to several thousand kilometres above the surface) in which charged particles are trapped and their behaviour is dominated by the Earth's magnetic field.
- Discuss qualitatively how the Earth's magnetic field provides protection from solar winds.
  Solar wind: A stream of radioactive and charged particles sent into space at high speeds due to reactions on the sun.

Electrostatics
(This section must be read in conjunction with the CAPS, p. 40–42.)

Two kinds of charge

- State that:
  - All materials contain positive charges (protons) and negative charges (electrons)
  - An object that has an equal number of electrons and protons is neutral (no net charge)
  - Positively charged objects are electron deficient and negatively charged objects have an excess of electrons
- Describe how objects (insulators) can be charged by contact (or rubbing) - tribo-electric charging.
  Tribo-electric charging: A type of contact electrification in which certain materials become electrically charged after they come into contact with different materials and are then separated (such as through rubbing). The polarity and strength of the charges produced differ according to the materials.

Charge conservation

- State that the SI unit for electric charge is the coulomb (C).
- State the principle of conservation of charge: The net charge of an isolated system remains constant during any physical process e.g. two charges making contact and then separating.
- Apply the principle of conservation of charge.
  When two identical conducting objects having charges Q_1 and Q_2 on insulating stands touch, each object has the same final charge on separation.
  Final charge after separation: $Q = \frac{Q_1 + Q_2}{2}$
  NOTE: This equation is only true for identically sized conductors on insulated stands.

Charge quantization

- State the principle of charge quantization: All charges in the universe consist of an integer multiple of the charge on one electron, i.e. $1,6 \times 10^{-19}$ C.
- Apply the principle of charge quantization: $Q = nq_e$, where $q_e = 1,6 \times 10^{-19}$ C and n is an integer.

Force exerted by charges on each other (descriptive)

- State that like charges repel and opposite charges attract.
- Explain how charged objects can attract uncharged insulators because of the polarisation of molecules inside insulators.
  Polarisation: The partial or complete polar separation of positive and negative electric charge in a system.

Electric Circuits
(This section must be read in conjunction with the CAPS, p. 42–45.)

Terminal potential difference and emf

- Define potential difference across the ends of a conductor as the energy transferred per unit electric charge flowing through it. In symbols: $V = \frac{W}{Q}$
  Potential difference is measured in volts (V).
- Define emf as the work done per unit charge by the source (battery). It is equal to the potential difference measured across the terminals of a battery when no charges are flowing in the circuit.
- Define terminal potential difference as the voltage measured across the terminals of a battery when charges are flowing in the circuit.
- Do calculations using $V = \frac{W}{Q}$.

Current

- Define current strength, I, as the rate of flow of charge. It is measured in ampere (A), which is the same as coulomb per second.
- Calculate current strength in a conductor using the equation $I = \frac{Q}{\Delta t}$.
  Q is the symbol for electric charge measured in coulomb (C). One coulomb is defined as the charge transferred in a conductor in one second if the current is one ampere.
- Indicate the direction of conventional current (from positive to negative) in circuit diagrams using arrows.

Measurement of potential difference and current

- Draw a diagram to show how to correctly connect an ammeter to measure the current through a given circuit element. An ammeter is connected in series and has a very low resistance.
- Draw a diagram to show how to correctly connect a voltmeter to measure the potential difference across a given circuit element. A voltmeter is connected in parallel and has a very high resistance.

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