Exploring science teachers’ strategies for addressing misconceptions about electric circuits

by

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DEDICATION

I dedicate this dissertation to my deceased mother, **PHELEPINA PHIFADI**, who despite suffering from epilepsy and could not be employed as a result, always made sure that we not only survived but prospered. I wish that you live long enough to enjoy the fruits of your sacrifices. **Robala ka kgotso Hlapjadi!**

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ABSTRACT

Despite interventions provided by teachers who teach electric circuits, misconceptions persist and are a barrier to learners' conceptual understanding. Although literature show findings and recommendations on misconceptions in science education, there is limited attention given to how teaching strategies used by teachers can address them. This study explored Grade 11 Physical Science teachers' awareness of common misconceptions in electric circuits, as well as their planned and enacted teaching strategies to address these misconceptions. Data was collected through a qualitative case study approach. This was done by means of a questionnaire for teachers and a test for learners adapted from the questionnaire, teacher interviews and lesson observations during feedback. The study relied on Pedagogical Content Knowledge (PCK) and Teacher Talk as conceptual frameworks used to analyse the teachers' planned strategies and the enacted strategies. The findings demonstrate that while some teachers showed awareness of common misconceptions, their planned strategies were centred around curricular saliency and not representations or conceptual teaching strategies. Also, the enacted strategies were mostly authoritative and non-interactive, focusing on telling learners the correct answers without engaging them conceptually. Thus, the study underscores the necessity for professional development that incorporates PCK components, as well as dialogic and interactive teaching strategies to effectively address misconceptions and promote conceptual understanding in science classrooms.

Keywords: Misconceptions, Electric Circuits, Physical Sciences, Pedagogical Content Knowledge (PCK), Teacher Awareness, Teaching Strategies, Learner Understanding, Feedback, Teacher Talk, Conceptual Change.

NAGANWAGO (SEPEDI)

Go sa šetšwe ditsenogare tšeo di filwego ke barutiši bao ba rutago dipotologo tša mohlagase, dikgopolo tše di fošagetšego di a phegelela gomme ke lepheko go kwešišo ya dikgopolo ya baithuti. Le ge e le gore dingwalo di bontšha dikhwetšo le ditšhišinyo ka ga dikgopolo tše di fošagetšego thutong ya mahlale, go na le šedi ye e lekanyeditšwego yeo e fiwago ka fao maano a go ruta ao a šomišwago ke barutiši a ka di rarollago ka gona. Thuto ye e lekotše temogo ya barutiši ba Mphato wa 11 wa Fisikale Saensese ka ga dikgopolo tše di fošagetšego tše di tlwaelegilego ka dipotologong tša mohlagase, gammogo le maano a bona a go ruta ao a rulagantšwego le ao a šomišitšwego go rarolla dikgopolo tše tše di fošagetšego. Datha e kgobokeditšwe ka mokgwa wa nyakišišo ya mohlala wa boleng. Se se dirilwe ka lenaneopotšišo la barutiši le teko ya baithuti yeo e fetotšwego go tšwa lenaneopotšišong, dipoledišano tša barutiši le ditebelelo tša dithuto nakong ya ditshwaotshwao. Thuto e be e ithekgile ka Tsebo ya Diteng tša Thuto (PCK) le Polelo ya Barutiši bjalo ka ditlhako tša dikgopolo tšeo di šomišitšwego go sekaseka maano ao a rulagantšwego a barutiši le maano ao a dirilwego molao. Dikutollo di laetša gore le ge barutiši ba bangwe ba bontšhitše temogo ya dikgopolo tše di fošagetšego tše di tlwaelegilego, maano a bona ao a rulagantšwego a be a tsepame go dikologa go tšwelela ga kharikhulamo e sego dikemedi goba maano a go ruta a dikgopolo. Gape, maano ao a šomišitšwego e be e le bontši bja taolo ebile a sa dirišane, a lebeletše kudu go botša baithuti dikarabo tše di nepagetšego ntle le go ba tsenya letsogo ka kgopolo. Ka go realo, nyakišišo e gatelela tlhokego ya tlhabollo ya profešene yeo e akaretšago dikarolo tša PCK, gammogo le maano a go ruta a poledišano le a tirišano go rarolla ka mo go atlegilego dikgopolo tše di fošagetšego le go tšwetša pele kwešišo ya dikgopolo ka diphapošing tša mahlale.

Mantšu a bohlokwa: Dikgopolo tše di fošagetšego, Dipotologo tša Mohlagase, Mahlale a Mmele, Tsebo ya Diteng tša Thuto (PCK), Temogo ya Morutiši, Maano a go Ruta, Kwešišo ya Moithuti, Ditshwayotshwayo, Polelo ya Morutiši, Phetogo ya Kgopolo.

TSHIHUMBULELWA (TSHIVENDA)

Naho hu na vhudzheneleli ho ṋetshedzwaho nga vhagudisi vhane vha funza sekithi dza muḓagasi, mihumbulo yo khakheaho i kha ḓi vha hone nahone ndi tshithivheli kha u pfesesa ha vhagudi ha mihumbulo. Naho maṅwalwa a tshi sumbedza mawanwa na themendelo dza mihumbulo yo khakheaho kha pfunzo ya saintsi, hu na ṱhogomelo ṱhukhu yo ṋewaho kha uri zwiṱirathedzhi zwa u funza zwo shumiswaho nga vhagudisi zwi nga zwi tandulula hani. Ngudo iyi yo ṱoḓisisa nḓivho ya vhagudisi vha Gireidi ya 11 ya sayense dza nndwa nga ha mihumbulo yo khakheaho yo ḓoweleaho kha sekithi dza muḓagasi, khathihi na zwiṱirathedzhi zwavho zwa u funza zwo pulaniwaho na u vhewa mulayoni u itela u tandulula mihumbulo iyi yo khakheaho. Datha yo kuvhanganywa nga nḓila ya ngudo ya tsumbo ya vhuimo. Hezwi zwo itwa nga nḓila ya mbudzisavhathu ya vhagudisi na mulingo wa vhagudi wo ṱanganedzwaho u bva kha mbudzisavhathu, inthavhiyu dza vhagudisi na u sedza ngudo nga tshifhinga tsha u ṋea vhupfiwa. Ngudo yo ḓitika nga Nḓivho ya Zwi re Ngomu ya Pedagogiki (PCK) na Nyambedzano ya Vhagudisi sa muhanga wa mihumbulo wo shumiswaho u sengulusa zwiṱirathedzhi zwo pulaniwaho zwa vhagudisi na zwiṱirathedzhi zwo vhewaho mulayoni. Mawanwa a sumbedza uri naho vhaṅwe vhagudisi vho sumbedza u ḓivha mihumbulo yo khakheaho yo ḓoweleaho, zwiṱirathedzhi zwavho zwo pulaniwaho zwo vha zwo sedza kha u bvelela ha kharikhuḽamu hu si kha vhuimeleli kana zwiṱirathedzhi zwa u funza zwa mihumbulo. Hafhu, zwiṱirathedzhi zwo vhewaho zwo vha zwi na maanḓa vhukuma nahone zwi sa ṱanganelani, zwo sedza kha u vhudza vhagudi phindulo dzo teaho hu si na u vha dzhenisa kha muhumbulo. Ngauralo, ngudo i ombedzela ṱhoḓea ya mveledziso ya phurofeshinaḽa ine ya katela zwipiḓa zwa PCK, khathihi na zwiṱirathedzhi zwa u funza zwa nyambedzano na zwa vhukwamani u itela u tandulula nga nḓila i bvelelaho mihumbulo yo khakheaho na u ṱuṱuwedza u pfesesa mihumbulo kha kilasi dza saintsi.

Maipfi a ndeme: Mihumbulo yo khakheaho, Sekhethe dza Muḓagasi, Saintsi ya Muvhili, Nḓivho ya Zwi re Ngomu zwa Pedagogiki (PCK), Nḓivho ya Vhagudisi, Zwiṱirathedzhi zwa u Funza, Pfeseso ya Mugudi, Mbuelo, Nyambo ya Mugudisi, Tshanduko ya Muhumbulo.

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1. CHAPTER ONE: INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

This chapter introduces this study, which explores how Physical Science teachers address learners' misconceptions in the topic of electric circuits. This is done by focusing on three aspects: the teachers' awareness of common misconceptions, their planned teaching strategies to address the misconceptions, and the teaching strategies they enact when giving feedback to learners after a test. The chapter also provides an overview of the difficulties faced by learners in understanding electric circuits and underscores the need to investigate how teachers interpret and react to learner thinking in this context. The background of this study, as well as the problem the study seeks to address, the purpose and objectives, and the research questions of the study are also addressed in this chapter

1.2 BACKGROUND OF THE STUDY

Common misconceptions held by learners about electric circuits are well documented in science education literature, and they are known to hinder the learners' conceptual understanding (Moodley and Gaigher, 2019). These alternative conceptions often stem from the learners' intuitive reasoning, their daily language, or the learners' prior knowledge and tend to persist even after instruction (Aligo, et al., 2021). Even though the presence and impact of these misconceptions are widely recognised, there is limited research on how teachers address them in a classroom context, especially when giving feedback after assessing the learners.

In the South African Physical Sciences curriculum, the topic of electric circuits is taught across Grades 8 to 12, yet the National Senior Certificate examination diagnostic reports consistently show that learners continue to struggle with basic and advanced circuit concepts (DBE, 2020; 2021; 2022). Notwithstanding this, a lot of research has focused on identifying misconceptions from the perspective of learners, instead of exploring how teachers anticipate and address these misconceptions (Moodley and Gaigher, 2019).

This study shifts the focus from the learners and moves it towards science teachers, mainly their awareness of the common learners' misconceptions in electric circuits, what teaching strategies they plan to use to address these misconceptions, and how they enact these teaching strategies in practice, particularly when giving feedback to learners post-assessment. Teaching strategies play a vital role in either correcting or reinforcing learners' misconceptions (Vosniadou, 2020). Teachers who show awareness of common learners' misconceptions are better equipped to design directed intervention plans and use conceptual teaching strategies that promote meaningful understanding (Singh, 2024). However, many teachers tend to use formula-based or procedural teaching strategies, which often fail to effectively engage learners in the type of reasoning needed for conceptual change (Espinosa, 2019). How teachers provide feedback after assessing the learners, whether it is authoritative or dialogic, interactive or non-interactive, also influences whether the learners confront their misconceptions or just accept the presented answers without understanding the reasoning behind them.

By exploring the teachers' teaching strategies for addressing the misconceptions in electric circuits, this study seeks to contribute to improved Physical Science teaching strategies and a deeper understanding of how awareness of misconceptions, planned and enacted teaching strategies, can be used to promote conceptual clarity. These three dimensions, teachers' awareness of common learners' misconceptions, and planned teaching strategies and enacted teaching strategies during feedback sessions, guide this study. While awareness of common misconceptions, according to Moodley and Gaigher (2019) refers to the teachers' ability to anticipate learners' incorrect ideas, planning in the context of this study, as Allen (2019) puts it, involves the teacher's ability to anticipate learners' incorrect ideas refers to how teachers devise teaching strategies to address the common misconceptions, and the enacted teaching strategies are what teachers do during feedback after assessment (Alonzo, et al., 2019).

1.3 RATIONALE

In the teaching of the Physical Sciences subject, learners' understanding of electric circuits is often hindered by misconceptions. A notable challenge is the endurance of these misconceptions as learners progress through grade levels, despite expectations that they should have been addressed in earlier stages of their education. Unfortunately, they pose a tough barrier to learners' acquisition of accurate scientific knowledge and the development of robust conceptual frameworks.

In the context of electric circuits, learners often grapple with fundamental distinctions between current and voltage, the interpretation of circuit diagrams, and the comprehension of relationships within circuit configurations. These challenges are not unique to a single classroom but are pervasive, extending to a national scale. The Department of Basic Education's (DBE) diagnostic report on the 2022 National Senior Certificate examination highlights that among the persistent challenges that Grade 12 students encounter is understanding circuit diagrams and distinguishing between the subtleties of resistance, voltage, and current flow (DBE, 2023).

These observations align with those in published findings that have consistently highlighted the existence of misconceptions among science learners, particularly in the context of electric circuits (Moodley & Gaigher, 2015; Moodley & Gaigher, 2019; Aligo, Branzuela, Faraon, Gordon, & Orleans, 2021). To effectively address these misconceptions, teachers must first understand and expose them, an idea that is well supported by Moodley and Gaigher (2019). While it is acknowledged that misconceptions are well documented in electric circuits, research into teachers' strategies used to address these misconceptions when giving feedback is still missing in the literature.

1.4 PROBLEM STATEMENT

The problem of this study is that even though misconceptions in electric circuits are well documented in science education literature, there is a scarcity of research on how science teachers plan and enact teaching strategies to address these misconceptions, especially during feedback sessions after assessment. Notwithstanding a comprehensive curriculum coverage across Grades 9 to 12 in the subject of Physical Sciences, learners are still struggling with key electric circuits concepts, as evidenced by consistently poor performance reported in the Department of Basic Education (DBE) National Senior Certificate diagnostic reports for the years 2020 – 2024. This study focuses particularly on Grade 11 Physical Sciences teachers because electric circuits are a key component of the Grade 11 curriculum and lay the foundation for success in Grade 12. This study addresses the gap by exploring Physical Sciences teachers' awareness of common misconceptions in electric circuits, their planned teaching strategies, and how the teachers enact these teaching strategies during feedback.

1.5 PURPOSE OF THE STUDY

The purpose of this study was to investigate teachers' awareness of learners' misconceptions in electric circuits as well as their planned and enacted teaching strategies to address the misconceptions when providing feedback to learners. This study extends previous research by Moodley and Gaigher (2019) that explored teachers' perceptions about electric circuits in relation to their understanding of learners' misconceptions. By gaining insights into effective teaching strategies, the research seeks to contribute to the development of improved science education practices and the enhancement of learners' understanding of electric circuits. This study also provides valuable information for teachers and curriculum developers to improve the quality of science education in South African schools.

1.6 RESEARCH AIMS AND OBJECTIVES

1.6.1 Aims of the study

This study aimed to explore teachers' awareness of learners' misconceptions in electric circuits, strategies they used to address the misconceptions, and when giving feedback to learners after writing a test designed to elicit misconceptions in electric circuits. These aims were achieved through the following objectives:

1.6.2 Objectives of the study

The main objective of this study was to extend Moodley and Gaigher's (2019) study that explored teachers' perceptions about teaching electric circuits and their understanding of learners' misconceptions. Also, this study explored how the participant teachers addressed the misconceptions when giving feedback to learners. Hence, the objectives of this study were to:

- Determine the extent to which teachers were aware of the misconceptions revealed by their learners in electric circuits.
- Investigate teachers' planned teaching strategies to address the misconceptions
- Explore how teachers addressed the misconceptions in electric circuits during teaching, when giving feedback to learners.

1.6.3 Research questions:

My study aimed to answer the following questions:

- To what extent are teachers aware of the misconceptions revealed by their learners in electric circuits?
- How do teachers plan to address the misconceptions?
- How do the teachers address the misconceptions in electric circuits during teaching when giving feedback to learners?

1.7 RESEARCH ASSUMPTIONS

This study was designed and conducted under certain assumptions, including about the intended data that was to be collected from participants. These assumptions included the belief that participants would provide honest and truthful responses when addressing their understanding of electric circuits and their misconceptions. Additionally, assumptions were drawn from existing literature in the field of science education, which may influence the interpretation of learners' misconceptions and the effectiveness of teaching strategies in addressing these misconceptions. Common-sense assumptions were developed to conduct the study, such as the prevalence of specific misconceptions among learners at different educational levels. Furthermore, warranted assumptions, such as assuming that addressing misconceptions can lead to improved learning outcomes for learners, were made. I, therefore, posited that the assumptions made in this study were based on a comprehensive review of the existing literature on misconceptions in electric circuits and were necessary for guiding the research process and forming the basis for the study’s objectives and methodologies.

1.8 CLARIFICATION OF KEY CONCEPTS

To have a shared understanding of the concepts used in this study, the terms that follow are clarified by the theoretical frameworks adopted:

Misconceptions: In this study, these refer to scientifically incorrect cognitive frameworks or beliefs held by learners, which usually result from their daily experiences, inaccurate prior learning, or ambiguous analogies. It is therefore that in this study, misconceptions are considered as structured alternative conceptions that disrupt correct scientific understanding (Vosniadou, 2020).

Electric circuits: This topic within the Physical Sciences curriculum involves the study of electric current, voltage, resistance, energy transfer, and the configuration of components in series and parallel. (Beil, et al., 2023).

Teacher awareness: This refers to the degree to which teachers can anticipate or identify learners' misconceptions. This includes their ability to predict learners' errors and explain how such errors may occur based on conceptual challenges learners face (Gaigher, 2017).

Teaching strategies: These are teaching approaches and methods used by the teachers to promote learning (Killen & O'Toole, 2023). In this study, teaching strategies are separated into planned strategies before instruction and enacted strategies used during feedback and classroom teaching.

Feedback: In this study's context, feedback refers to the teaching interactions that occur after a test, where the teacher addresses the learners' misconceptions and conceptual errors, intending to promote conceptual change (Carless & Winstone, 2023).

Teacher Talk: This refers to the discourse used by teachers during their lessons and feedback. It includes dialogic and authoritative interactions, which influence the potential for conceptual learning (Scott, et al., 2006).

Pedagogical Content Knowledge (PCK): This refers to the integration of teachers' subject matter knowledge with pedagogical strategies to make content accessible to learners. This study focuses on three key components of PCK: curricular saliency, representations, and conceptual teaching strategies (Chan et al., 2019).

1.8 DELIMITATION OF THE STUDY

This study was delimited to Grade 11 teachers who are teaching electric circuits and their learners from three secondary schools in Moletlane circuit, Capricorn South district in Limpopo Province, South Africa. The study was focused on the electric circuits within the Physical Sciences curriculum, and the scope of the study did not include other Physical Sciences topics or extend to Grade 12 or Grade 10 learners. Additionally, the data sources for this study were limited to a questionnaire, interviews and lesson observations during the second term of the year. The small, convenience sample limits generalisability and suggests that findings are exploratory.

1.8 CHAPTER SUMMARY

This chapter introduced the study, emphasising the challenge of persistent misconceptions in electric circuits and the impact they have on conceptual understanding in Physical Sciences education. It charted the rationale for the study, the aims of the research, and the research questions that framed the study into the teachers' awareness of the learners' misconceptions and their strategies for addressing these misconceptions. It also presented the assumptions and delimitations of the study, setting the foundation for the literature review and research methodology to follow.

1.9 CHAPTER OUTLINE

CHAPTER 1: INTRODUCTION AND BACKGROUND TO THE STUDY

This chapter provides an overview of the research problem and purpose, as well as the significance of the study. It also gives a background to the study and the context in which it was conducted.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews existing literature on learners' misconceptions related to electric circuits and strategies used by science teachers to address them. It also explores the frameworks that guided the study.

CHAPTER 3: RESEARCH METHODOLOGY

This chapter describes the research design and methods used in the study, including the sampling procedure, data collection instruments, and data analysis techniques. Also discussed are ethical considerations and measures of trustworthiness.

CHAPTER 4: TEACHERS' AWARENESS AND PLANNED STRATEGIES

This chapter presents the data collected from the teachers' interviews that explored their awareness of the common misconceptions in electric circuits and their planned strategies to address the misconceptions, and the analysis of the data through the lens of Pedagogical Content Knowledge (PCK).

CHAPTER 5: TEACHERS' ENACTED STRATEGIES DURING FEEDBACK

This chapter presents the data collected through the observation of teachers' feedback sessions to the learners and the analysis of the enacted strategies through the lens of Teacher Talk.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

In this chapter, the main results of the research are outlined and their significance for science education in South Africa. Additionally, potential directions for future research are suggested, and the study's limitations are critically evaluated. Based on the findings, recommendations are made to enhance science education practices.

2. CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews literature about teachers' strategies for addressing learners' misconceptions about electric circuits. The review is centred on how the teachers become aware of common learners' misconceptions, the teaching strategies that they plan to use to address these misconceptions, and how they enact these teaching strategies in the actual classroom during feedback. The chapter also discusses key concepts central to this study as well as a conceptual framework that is informed by the Pedagogical Content Knowledge (PCK) and Teacher Talk frameworks.

2.2 UNDERSTANDING MISCONCEPTIONS IN ELECTRIC CIRCUITS

2.2.1 Nature of misconceptions

Misconceptions, also known as naïve theories (Vosniadou, 2019), intuitive beliefs (Shtulman, 2022) or alternative conceptions (Fujii, 2020), are systematic misunderstandings that conflict with scientifically accepted knowledge. Contrasting simple knowledge gaps, which often represent an absence of knowledge, misconceptions are deeply ingrained mental models that learners construct based on their personal experiences, preexisting knowledge, and intuitive reasoning (Sands, 2021). This is because they are often internally consistent and reinforced by daily experiences, and they are resistant to change, even after formal teaching (Vosniadou, 2019). For this study, misconceptions are defined as structured, preexisting alternative conceptions that interfere with learners' ability to develop scientifically accurate understandings of electric circuits (Vosniadou, 2020; Özmen, 2023). This definition acknowledges that misconceptions are not random errors but instead are cognitive models that shape how learners interpret new information (Vosniadou, 2019).

Misconceptions arise from multiple teaching and cognitive sources (Chew & Cerbin, 2021). Understanding these sources is vital for designing teaching strategies that are effective in promoting conceptual change (Vosniadou, 2020). The major sources of misconceptions include daily experiences and intuition, where learners develop intuitive explanations for scientific concepts based on their sensory experiences (Kelemen, 2019). Learners do not gain new knowledge in isolation, they incorporate it with mental models that already exist (Mayer, 2019). When pre-existing knowledge is incomplete or incorrect, new information can be misinterpreted, thus reinforcing misconceptions (Suprapto, 2020). This occurrence, known as knowledge interference, explains why some misconceptions persist even after direct instruction (Butterfus & Kendeou, 2020). The way science is taught can either challenge or reinforce misconceptions (Allen, 2019). If a teaching approach emphasises memorisation and procedural problem-solving over conceptual understanding, learners may retain misconceptions (Fujii, 2020). Studies by Allen (2019), Fujii (2020) and Sands (2021) have indicated that when teachers fail to address misconceptions, their learners frequently revert back to their prior mental models despite having learned new information. Also, teachers frequently use models and analogies to assist their learners in understanding abstract scientific concepts. However, if such analogies are misleading or incomplete, they can end up reinforcing misconceptions (Moodley & Gaigher, 2019). An example of this is the "water flow" analogy often used to explain electric circuits that can lead learners to believe that current behaves like a fluid and thus cause confusion between voltage and current (Burde & Wilhelm, 2020). Additionally, some science textbooks sometimes contain incorrect diagrams or oversimplified definitions that contribute to misconceptions (Vosniadou, 2020). For example, some textbooks depict electric current as decreasing as it moves through a circuit, and this reinforces the "attenuation model misconception'' (Bradley & Moodie, 2021). Also, the static representation of circuits in textbooks may fail to convey the dynamic nature of electrical interactions and, hence, lead to fragmented conceptual understanding (Widodo, et al., 2018).

Once these misconceptions are formed, they are difficult to address because learners interact with new information in a way that seeks to confirm their pre-existing beliefs (Lawson , et al., 2019). Also, learners who focus on memorisation instead of conceptual understanding are likely to retain misconceptions (Chew & Cerbin, 2021). Additionally, teachers who do not actively expose and address misconceptions may accidentally reinforce them (Singh, 2024).

2.2.2 Common misconceptions in electric circuits

How learners understand electric circuits is often structured by intuitive but scientifically incorrect conceptions (Moodley & Gaigher, 2019). These misconceptions persist even after formal teaching, and they form coherent frameworks that resist change (Vosniadou, 2019). Over the years, researchers such as Wainwright (2007), Sangam (2012), Van der Merwe and Gaigher (2011), and Moodley and Gaigher (2019) have documented recurring misconceptions that hinder conceptual learning in electricity, particularly at the school level. Table 2.1 below summarises some of the most common misconceptions identified in the literature and correct conception.

Table 1.1: Summary of the most common misconceptions identified in literature and correct conception

Misconception	**Correct conception**
Attenuation model: the belief by learners that electric current is “used up” as it passes through components such as light bulbs, resulting in less current being available in later parts of the circuit (Van der Merwe & Gaigher, 2011)	Current is conserved in a series circuit; it remains the same through all the components (Paul, 2001).
Clashing current model: the belief that current flows from both battery terminals and meets in the middle of the circuit (Moodley & Gaigher, 2019).	Current flows in a single direction in a complete circuit, from the positive to the negative terminal (Von Meier, 2024).
Weakening current model: the belief that current becomes weaker the farther it travels from the battery (Van der Merwe & Gaigher, 2011).	The current remains constant throughout a series circuit, regardless of the position of components (Falloon, 2019).
Empirical rule model: the belief that bulbs further from the battery are dimmer due to distance (Suryadi, et al., 2020)	The brightness of the bulb depends on the current and resistance, not the physical distance from the battery (Ivanjek, et al., 2021)
Confusion between current and voltage: the misunderstanding where voltage is perceived as a substance that flows like current (Moodley & Gaigher, 2019).	Voltage does not flow; it is the potential difference between two points (Von Meier, 2024)

These misconceptions in Table 2.1 frequently originate from learners’ prior experiences and intuitive reasoning, which are influenced by their daily language and analogies (Suprapto, 2020). Research conducted in South Africa, including that by Van der Merwe (2011) furtherly indicated that some misconceptions are reinforced by classroom practices that underscore procedural knowledge instead of conceptual understanding. Understanding the persistence and nature of these misconceptions is crucial for informing teaching strategies and designing interventions that can effectively promote conceptual change in electric circuits.

Even though understanding the nature and persistence of learners' misconceptions in electric circuits is pivotal, investigating how teachers respond to these misconceptions in their teaching is equally as important. The sections that follow review the literature that exist on the teachers' awareness of learners' misconceptions, the teachers' PCK, the role of Teacher Talk, and the particular teaching strategies used to address learner misconceptions in practice, especially through feedback.

2.3 TEACHERS' AWARENESS OF MISCONCEPTIONS

The awareness of misconceptions by teachers plays a vital role in structuring teaching strategies and influencing the effectiveness of how misconceptions are addressed during lessons (Singh, 2024). Moodley and Gaigher (2019) have indicated that some teachers who possess a strong understanding of common misconceptions in electric circuits are better equipped to predict learners' difficulties and enact strategies that promote conceptual change. In contrast, the lack of awareness of misconceptions by teachers may reinforce inaccurate ideas through their teaching strategies or not be able to effectively challenge their learners' misconceptions (Van der Merwe, 2011).

Teachers' ability to uncover and address learners' misconceptions is influenced by their content knowledge (CK) and Pedagogical Content Knowledge (PCK) (Suharta & Parwati, 2020). PCK, which also includes the teachers' knowledge of learners' difficulties and effective teaching strategies, is especially pivotal in addressing misconceptions in science education (Suharta & Parwati, 2020). According to Van der Merwe (2011), teachers who have a strong PCK can better anticipate the misconceptions that learners may have and accordingly adapt their teaching strategies. By contrast, other studies have indicated that teachers who have limited knowledge of electric circuits struggle to differentiate between conceptual understanding and procedural knowledge (Gaigher, 2014; Moodley and Gaigher, 2019; Gumede, 2019). In the absence of a deeper understanding of concepts related to electric circuits, teachers may inadvertently reinforce misconceptions through the use of incomplete analogies, misleading explanations, and procedural teaching strategies that fail to challenge misconceptions held by the learners (Moodley & Gaigher, 2019; Fujii, 2020).

How teachers plan their lessons and design interventions is directly influenced by their awareness of learners' misconceptions (Singh, 2024). Research has shown that when teachers are aware of common misconceptions, they are likely to use diagnostic assessments to uncover misconceptions before they teach learners (Resbiantoro & Setiani, 2022). They are also likely to use multiple representations, such as interactive simulations, circuit diagrams, and hands-on activities, to clarify concepts (Moodley & Gaigher, 2019). Additionally, they are more likely to implement cognitive conflict strategies to probe learners' misconceptions (Suharta & Parwati, 2020). However, when teachers are not aware of learners' misconceptions, they frequently resort to procedural problem-solving and rote teaching, an approach that does not promote conceptual understanding (Themane, 2022). For instance, teachers who are not aware of the "attenuation model" misconception, the belief that current decreases as it moves through a circuit, are more likely to focus on calculating resistance and voltage without clearly addressing why current remains the same in a series circuit (Bradley et al., 2019).

Several studies have investigated the relationship between teachers' awareness of misconceptions and the effectiveness of their teaching strategies. Van der Merwe and Gaigher (2011) found that many Physical Science teachers did not exhibit clear knowledge of learners' misconceptions about electric circuits, which leads to remedial strategies that are not effective. Also, Gaigher (2014) highlighted that improving the teachers' knowledge of learners' misconceptions improved their ability to employ conceptual teaching strategies instead of purely procedural strategies. Moodley and Gaigher (2019) in their study, they found that experienced teachers rely on intuition as opposed to relying on research-based strategies to address misconceptions, hence, highlighting the need for targeted professional development. In another study, Mazibe et al. (2020) reported similar patterns in Physical Sciences teaching, where the teachers' awareness of common misconceptions in graphs of motion influenced whether they adopted interactive teaching strategies.

Teachers' awareness of misconceptions is a pivotal factor in the effectiveness of the teaching strategies aimed at conceptual change. Recent studies, such as Weitzel & Blank (2020); Suharta & Parwati (2020); Li et al. (2024), posited that teacher training needs to focus on improving teachers' PCK linked to learner misconceptions, contrasted with concentrating only on improving content knowledge. Addressing this gap through curriculum design and professional development could lead to more efficient science teaching and improved learner outcomes.

2.4 THE ROLE OF PCK IN ADDRESSING MISCONCEPTIONS

PCK, as mentioned earlier, was conceptualised by Shulman (1986) and refers to the blend of subject matter knowledge and pedagogical strategies that enables teachers to make content accessible and understandable to learners. In science education, PCK includes the teachers' understanding of common misconceptions held by learners, the strategies for addressing such misconceptions, and the teachers' ability to design their lessons that facilitate conceptual understanding (Alonzo, et al., 2019). PCK is especially important in correcting misconceptions as it bridges the gap between the content knowledge and teaching decisions of the teachers (Mavhunga & Van der Merwe , 2020). And, as Moodley and Gaigher (2019) posited, in addition to knowing the concepts that their learners find difficult to deal with, teachers who possess a strong PCK are also to use teaching strategies, analogies and questioning to address the misconceptions that their learners might have. Other studies have found that teachers with a well-developed PCK can effectively predict their learners' misconceptions and plan strategies that promote meaningful learning (Nilsson & Vikström, 2015; Fraser, 2016; Wongsopawiro et al., 2017; Gess-Newsome et al., 2019; Nilsson & Karlsson, 2019). On the other hand, teachers who have a limited PCK tend to revert to procedural teaching, and this approach cannot effectively address the learners' misconceptions (Nilsson & Vikström, 2015). Mavhunga (2012), Mavhunga & Rollnick (2017) and Chan et al. (2019) posited that to effectively address misconceptions, three components of PCK are vital, which are curricular saliency, representations, and conceptual teaching strategies.

As explained earlier, curricular saliency refers to the ability of the teacher to identify important concepts in a topic, determine how these concepts are connected and then sequence them logically in their lessons (Rollnick & Mavhunga, 2016). This study found that teachers who demonstrated a strong curricular saliency were able to help their learners build coherent conceptual frameworks and thus reduced the possibilities of fragmented knowledge. In the context of electric circuits, this suggests that teachers with a stronger curricular saliency ought to emphasise the relationship between electric current, voltage, resistance and energy transfer instead of teaching them as isolated concepts.

An effective use of representations, like circuit diagrams, models, simulations, and models, can enhance conceptual understanding and aid in bridging the gap between the learners' pre-existing knowledge and abstract scientific concepts (Tippett, 2016). For instance, circuit diagrams could be useful in helping learners to visualise current paths, whilst interactive simulations can provide virtual representations of circuit behaviour. However, in their study, Gaigher (2014) noted that many Physical Sciences teachers lack the knowledge and confidence to implement appropriate representations to address misconceptions in electric circuits.

Conceptual teaching strategies include teaching approaches that are aimed at promoting conceptual understanding, like prediction-based learning, conceptual discussions, guided inquiry, and cognitive conflict strategies (Nasri, 2020). These kinds of strategies challenge learners to confront and correct their misconceptions (Chen & Techawitthayachinda, 2021). However, similar to what Mazibe et al. (2020) found, other studies have revealed that science teachers often rely on procedural teaching strategies and rarely use teaching strategies that encourage their learners to reflect on or revise their conceptual models (Moodley & Gaigher, 2019; Chew & Cerbin, 2021; Acosta-Gonzaga & Ramirez-Arellano, 2022).

Therefore, PCK is pivotal for addressing misconceptions in science teaching. Thus, the teachers who are better able to identify key ideas and curricular saliency, can use appropriate teaching tools, representations, and employ concept-focused pedagogies, conceptual teaching strategies, are better positioned to promote meaningful learning to their learners. However, studies like those of Gaigher (2014), Moodley and Gaigher (2019) and Mazibe et al. (2020) indicate that many teachers possess fragmented PCK, and this hinders their ability to effectively address misconceptions.

2.5 TEACHER TALK IN ADDRESSING MISCONCEPTIONS

Teacher talk is critical in structuring the teaching and learning environment and shaping how learners interact with scientific concepts, especially when addressing misconceptions (Bansal, 2018). Even though much of science teaching has traditionally relied on teacher-centred approaches, recent literature is increasingly emphasising the importance of classroom discourse that encourages learners to explain their thinking, challenge their misconceptions, and revise their understanding through guided engagement (Chen & Techawitthayachinda, 2021; Zwiers & Crawford, 2023; Biber, 2023). Studies have shown that the approach used by teachers when they talk during lessons, particularly when giving feedback, can either promote conceptual change or reinforce misconceptions (Allen, 2019; Moodley & Gaigher, 2019; Soysal & Soysal, 2023; Zwiers & Crawford, 2023). For instance, simply correcting the learners' answers without exploring the reasoning behind their incorrect answers often leads to surface-level learning and, thus, missed opportunities to clarify concepts (Scott, et al., 2006). On the other hand, questioning strategies which encourage learners to explain their thinking processes, and respond to cognitive conflict foster deeper learning and can often lead to lasting conceptual shifts (Chen & Techawitthayachinda, 2021; Zwiers & Crawford, 2023).

Studies by Bansal (2018), Vosniadou (2020) and Biber (2023) have demonstrated that teacher discourse is especially pivotal when dealing with persistent misconceptions. When teachers engage learners in extended discussions, provoke various perspectives, and respond to learners' ideas with well-thought-out prompts, they create environments for learners to challenge and correct their misconceptions (Zwiers & Crawford, 2023). In contrast, when feedback is authoritative and non-interactive, learners perceive their misconceptions as just mistakes that need to be corrected instead of conceptual frameworks to be explored and reshaped (Boyd, 2023). Despite this literature, evidence from classroom studies continues to reveal that many teachers rely on authoritative, monologic forms of interaction, even in instances where teachers are aware of the learners' misconceptions (Soysal & Soysal, 2023; Tao & Chen, 2023). Therefore, improving teacher talk involves creating epistemic spaces where learners can challenge their thinking, test it against conceptual evidence, and reconstruct scientifically accurate ideas, in addition to enhancing communication.

2.6 TEACHING STRATEGIES FOR ADDRESSING MISCONCEPTIONS

Misconceptions in science education, especially in domains such as electric circuits that are very abstract, need more than just content delivery for effective remediation (Moodley & Gaigher, 2019). Teaching strategies ought to be intentionally shaped to engage learners in active sense-making processes that challenge and reconstruct their prior knowledge (Reid & Ali, 2020). In this section, I discuss evidence-based teaching strategies for addressing common misconceptions. The focus of the discussion is on direction instruction, inquiry-based strategies, the use of multiple-representations, and prediction-based strategies address common misconceptions that learners have about electric circuits.

2.6.1 Direct instruction versus inquiry-based strategies

Direction instruction, which is mostly characterised by teacher-led explanations and procedural demonstrations, has been the predominant strategy in science classrooms (Cairns & Areepattamannil, 2022). Even though this strategy can be effective for factual knowledge transmission, studies have found that it often does not engage learners' misconceptions, particularly when the approach used is authoritative and non-interactive (Scott, et al., 2006). It normally leads to learners memorising standardised facts without understanding their conceptual foundations, thus leading to persistent misconceptions. On the other hand, inquiry-based teaching places learners as active participants in their knowledge construction (Chikaluma, et al., 2022).

2.6.2 Use of multiple representations

Using multiple representations like simulations, circuit diagrams, analogies, and verbal explanations enables learners to visualise and connect abstract concepts, thus supporting conceptual understanding (Preston, 2019). Guided enquiry, during which teachers ask questions or give learners structured problems and guide learners in exploring evidence, is especially effective in exposing and addressing misconceptions (Masilo, 2018). As Prayogi and Verawati (2020) asserted, learners are more likely to experience cognitive conflict and subsequently review their inaccurate thinking if they are engaged in inquiry-based activities. For instance, simulations allow learners to manipulate virtual circuit components and receive instant feedback, thus making abstract concepts such as current flow more tangible (Penn & Ramnarain, 2019). And analogies, even though they may reinforce misconceptions, if used cautiously by accompanying them with clarifications, can be effective (Gaigher, 2014). However, in practice, many teachers tend to rely on symbolic representations (formulae) and thus use fewer conceptual or visual tools (Mutodi & Mosimege, 2021). This then restricts opportunities for learners to revise their preconceptions and impedes meaningful learning.

2.6.3 Prediction-based and cognitive conflict strategies

Prediction-based strategies normally involve teachers asking learners to predict the outcomes of the circuit before testing it practically (Nasri, 2020). It works by prompting reflection and activating learners' prior knowledge, thus making it easy for misconceptions to be exposed (Dong, 2023). When the learners observe results that differ from their predicted results, a cognitive conflict is created, which serves as a key trigger for conceptual change (Vosniadou, 2020). Studies like Vosniadou (2019) demonstrate that a combination of prediction-based activities and structured reflection result in a deeper understanding and more effective correction of misconceptions. For example, if learners are asked to predict that adding a battery increases the brightness of all light bulbs in a parallel circuit connection, but when verifying their prediction practically, they find that only some bulbs behave as predicted, they are triggered to reassess their understanding of voltage and current distribution.

2.6.4 Empirical studies on teaching strategies to address misconceptions in electric circuits.

Various South African studies have explored how Physical Sciences teachers address common learners' misconceptions about electric circuits through teaching strategies. Moodley and Gaigher (2019) explored Grade 9 teachers' awareness of common learners' misconceptions about electric circuits. This study found that even when teachers recognised common learners' misconceptions, they mainly used procedural strategies such as factual explanations or demonstrations, with limited use of conceptual tools such as analogies. Similarly, Coetzee, Coetzee, and Gaigher (2022) reported that learners' misconceptions were connected to teaching strategies that lacked diagnostic focus and could not challenge learners' thinking. The study reported that in instances where practical activities were used to teach electric circuits, these practical activities were often confirmatory and failed to contribute meaningfully to conceptual change. Also, Mazibe, Coetzee, and Gaigher (2020), though their study focused on graphs of motion, it also highlighted that teachers' planned teaching strategies often did not align with their classroom practices. This disconnect reinforces the need to explore both the planned and enacted teaching strategies used to address misconceptions in science teaching.

International studies have also provided valuable insights into how teachers address misconceptions in electric circuits. Ivanjek et. al (2021), in a European study, that was conducted across multiple countries, developed a diagnostic tool for identifying misconceptions in electric circuits. The study's findings revealed that many teachers underestimated the persistence of misconceptions. And in Asia, Halim and Lestari (2019) explored teacher responses to misconceptions in Indonesia and the findings suggested that limited teacher preparation resulted in abstract and procedural teaching, which reinforced instead of correcting misconceptions. These findings highlight the global challenge of equipping teachers to identify and address misconceptions effectively.

2.7 THEORETICAL FRAMEWORKS

This study adopted a theoretical framework based on two main constructs: the Pedagogical Content Knowledge (PCK) for analysing the teachers' planned strategies and the Teacher Talk for analysing the teachers' enacted strategies. PCK provides insight into how teachers prepare to address misconceptions, whereas Teacher Talk explores how teaching strategies are implemented during feedback.

2.7.1 PCK as a framework for planned strategies

PCK signifies the incorporation of subject matter knowledge and pedagogy, which enables teachers to effectively plan and deliver content in ways that facilitate learners' understanding (Shulman, 1986). In the context of addressing misconceptions in electric circuits, this study considers three critical PCK components derived from the Grand Rubric that was proposed during the second PCK summit, designed to measure science teachers' enacted PCK (ePCK) within the framework of the Refined Consensus Model (RCM) of PCK (Chan, et al., 2019). The three components are: curricular saliency, representations, and conceptual teaching strategies.

Curricular saliency refers to the teachers' ability to identify and make priority, the main concepts and big ideas in the curriculum that are important to learners' understanding (Chan, et al., 2019). Van der Merwe and Gaigher (2011) showed that misconceptions in electric circuits frequently arise when learners fail to connect various ideas like the relationship between voltage, current and resistance. Teachers who prioritise main concepts and logically present them are more likely to prevent and effectively address misconceptions (Chew & Cerbin, 2021). Representations also play a critical role in clarifying abstract concepts (Chan, et al., 2019). Research such as that of Penn and Ramnarain (2019); Moodley and Gaigher (2019), suggest the effective use of multiple representations, like circuit diagrams, simulations, and real-world analogies, to enhance conceptual understanding. However, recent studies (Fujii, 2020; Mainali, 2021), have found that many teachers rely primarily on mathematical procedures, ignoring visual and conceptual representations that may assist in correcting misconceptions. Conceptual teaching strategies involve teaching approaches that are designed to promote deep understanding instead of rote memorisation (Chan, et al., 2019). According to Gaigher (2014) and Nasri (2020), these strategies include prediction-based discussions, inquiry-based learning, and cognitive conflict strategies, which directly challenge learners' misconceptions. Another study by Mazibe et al. (2020) found that teachers who lack strong PCK may fail to anticipate common misconceptions, and as a result of this, they might adopt generic teaching strategies that do not address learners' misconceptions effectively.

The effectiveness of the planned teaching strategies relies heavily on teachers' awareness of common learners' misconceptions. Studies have consistently shown that teachers with an awareness of learners' misconceptions are better equipped to design targeted interventions, whilst those with limited or no awareness frequently rely on traditional teacher-centred approaches that do not engage with learners' perceptions (Weitzel & Blank, 2020; Yarram, 2020).

2.7.2 Teacher Talk as a framework for enacted strategies

Even though planned teaching strategies shape the teachers' lessons, their enacted strategies, how the teachers interact with their learners during actual teaching and feedback, determine the extent to which conceptual change is facilitated (Russel & Martin, 2023). Teacher Talk serves as a lens for analysing these interactions, especially in terms of dialogic versus authoritative talk and interactive versus non-interactive discussion (Scott, et al., 2006). Dialogic teacher talk involves asking open-ended questions, discussions and scaffolding that allows learners to interrogate and explain their reasoning (Scott, et al., 2006). In contrast, authoritative talk focuses on presenting scientific knowledge as fixed and non-negotiable, and this hinders opportunities for learners' engagement in conceptual discussions (Russel & Martin, 2023). Studies such as those of Gillies (2019); Le, et al. (2023) and Tao & chen (2023) posit that dialogic teacher talk promotes conceptual change more effectively because it encourages the learners to explore and correct their misconceptions. To address misconceptions, effective teacher talk is needed. Interactive talk involves probing the learners' reasoning, providing scaffolding, and guiding them through conceptual conflicts, whereas non-interactive talk tends to be directive and corrective, thus offering little room for learner engagement (Wang, 2020). Recent studies suggest that when teachers use dialogic talk that is also interactive, their learners are more likely to consider their misconceptions and build scientifically correct understandings (Tam, 2021; Li, et al., 2023; Li, et al., 2024).

By incorporating PCK and Teacher Talk as complementary frames, this study explores the relationship between teachers' awareness of learners' misconceptions, their planned strategies to address those misconceptions, and their enacted strategies during feedback sessions. While strong PCK allows teachers to plan conceptually focused lessons (Mazibe, et al., 2020), how they communicate and interact with their learners during teaching and learning determines whether misconceptions are addressed effectively (Scott, et al., 2006). Understanding these dimensions provides valuable insight into the gap between the teachers' knowledge and their classroom practice, hence, contributing to more target professional development initiatives.

2.8 CHAPTER SUMMARY

This chapter reviewed literature related to misconceptions in electric circuits and how teachers respond to them through planned and enacted teaching strategies. The review began by exploring the nature and sources of common learners' misconceptions, and then went on to focus on the teachers' awareness of these misconceptions, their Pedagogical Content Knowledge (PCK), Teacher Talk, and the teaching strategies used to promote conceptual understanding. Studies from and abroad have shown that, even though many teachers are aware of misconceptions, they often struggle to implement the strategies that address these misconceptions effectively in actual classrooms. This supports the relevance of this study, which explores teachers' awareness of common learners' misconceptions, planned and enacted teaching strategies to address these misconceptions during feedback sessions post assessment.

3. CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This study explored the teachers' awareness of common misconceptions in electric circuits that may be held by their learners, their planned teaching strategies to address the misconceptions and their enacted strategies when they address the misconceptions during feedback. This chapter presents the procedures that were used in this study to research questions and achieve its aim. These entail the research paradigm for the study, the research methods, and the sampling strategies used in the study. Furthermore, the chapter discusses the data analysis used in this study. Lastly, issues of trustworthiness and ethical considerations followed in the study are presented.

3.2 RESEARCH PARADIGM

The research paradigm guiding a study denotes the fundamental belief system or worldview that defines the approach researchers take in designing and conducting their inquiry (Khatri, 2020). Davies and Fisher (2018) define research paradigms as ideas and beliefs of researchers on how to interpret the data collected for research. It encompasses the philosophical underpinnings that drive the collection, interpretation, and application of data within the research process (Tracy, 2019). Research paradigms can be thought of as the lenses through which researchers view and interpret the world (Davies & Fisher, 2018). According to Ugwu, et al. (2021), they encompass assumptions about the nature of knowledge (epistemology), the essence of reality (ontology), and how we come to understand the world (methodology). The paradigm chosen for a study reflects the researcher's conception of reality, dictates the research strategy, and influences how data are collected, analysed, and understood (Tracy, 2019). There are four common research paradigms according to Kankam (2019): critical paradigms defined as a worldview that focuses on exposing and challenging power structures, inequalities, and injustices in society through research aimed at transformation. Positivist defined as a scientific approach to research that assumes reality is objective, measurable, and can be understood through empirical observation and logical analysis , post – positivist that is a modified version of positivism that accepts reality can be approximated but not fully known, acknowledging researcher bias and the use of both quantitative and qualitative methods and interpretivist that is defined as a perspective that sees reality as socially constructed and seeks to understand participants' subjective meanings and experiences in specific contexts.

This study adopts the interpretivist paradigm, which posits that reality is not objective and exterior but is socially constructed through human interactions and experiences (Gephart, et al., 2018). Within this paradigm, knowledge is not discovered but rather created through the synthesis of these shared meanings (O'Donoghue, 2018). As indicated by Pervin and Mokhtar (2022), under the interpretivist paradigm, the epistemological stance is that knowledge is subjective and developed through understanding people's meanings and experiences. Ontologically, it implies that reality is multiple and interpreted differently by each person based on their experiences and interactions within the world (Bhaskar, 2020).

This paradigm was selected because it aligns with the intent to understand the varied strategies science teachers employ and the subjective experiences of learners in the context of misconceptions about electric circuits. Interpretivism allows for a deep exploration of these subjective meanings and the pedagogical nuances in the educational environment that impact learning (Rapley, 2018). According to Pervin & Mokhtar (2022), this qualitative paradigm allows the researcher to interpret data through the lens of the participants, offering a rich, detailed understanding of their perspectives. It is inherently flexible, capable of adapting to the complex nature of educational settings and the individual differences among learners and teachers (Hatch, 2023). By embracing this paradigm, the study aimed to uncover intricacies of pedagogical approaches and the nuanced ways in which learners conceptualise and misunderstand electric circuits, which may not be readily observable through quantitative measures. It offers a foundation for a more empathic and detailed examination of teaching and learning processes, which is vital for proposing informed strategies to address educational challenges effectively.

3.3 RESEARCH APPROACH

The research approach of a study encompasses the overarching strategies used to outline and design the research process (Leavy, 2022). It dictates how a study would have been conducted, guiding the researcher through the selection of methods, the collection and analysis of data, and the interpretation of results (Tracy, 2019). As Creswell (2020) posits, in conducting research, scholars might adopt a qualitative, quantitative, or mixed-methods approach. Qualitative research is exploratory, aimed at gaining a deep understanding of underlying reasons and motivations (Barroga, et al., 2023). Tracy (2019) alludes to the fact that it lends itself to the study of complex, contextual, and social phenomena, yielding rich detailed accounts. Quantitative research, by contrast, focuses on quantifying problems by generating numerical data that can be transformed into useable statistics (Creswell, 2020). As outlined in (Nardi, 2018), it often employs structured methods such as surveys, and it is best suited for testing hypotheses. Given the study's aim to delve into the nuanced perceptions and strategies of science teachers regarding electric circuit misconceptions, a qualitative approach is most suited. This approach enables an in-depth exploration of complex cognitive and pedagogical phenomena that are difficult to quantify, such as misconceptions and the various strategies employed to address them.

3.4 RESEARCH DESIGN

A research design is a strategy that specifies how a study will be carried out to achieve its research objectives and answer research questions (Hancock, et al., 2021).various research designs exist, such as experimental, quasi-experimental, and correlational designs. The design adopted for this investigation was a multiple case study. A case study is a method that involves studying a single or multiple cases to understand the complexity of the subject (Mohajan, 2018). In this study, a multiple case study was used to explore science teachers' awareness, planned, and enacted teaching strategies to address learner misconceptions about electric circuits across three different schools. The use of multiple cases allowed for cross-case comparison, strengthening the trustworthiness and transferability of the findings. The design is also exploratory, as it investigates an area where understanding is limited. This exploratory case study is qualitative in nature and seeks to understand how and why teachers act as they do when addressing misconceptions within their classroom environments.

3.5 SAMPLING STRATEGY, SITE SELECTION AND THE SELECTION OF PARTICIPANTS

Sampling is the process of selecting a subset of individuals, cases, or units from a larger population to participate in a study, with the aim of drawing conclusions that can be applied to the entire population (Etikan, Musa, & Alkassim, 2016). The sample for this research consisted of science teachers who taught Physical Science in Grade 11, as this grade includes the topic of electric circuits in its curriculum. The sampling frame was restricted to a list of all science teachers meeting the study's criteria within the Moletlane Circuit of the Capricorn South Education District, located in Limpopo Province. Limpopo is divided into five education districts: Capricorn South, Capricorn North, Mopani, Sekhukhune, and Vhembe. The Capricorn South District was selected due to its accessibility to the researcher, who is based within the district. Within Capricorn South, the Moletlane Circuit was conveniently selected because it includes schools that offer Physical Sciences at Grade 11 level and have a track record of participating in subject improvement initiatives. This setting was thus deemed suitable for exploring how science teachers engage with learner misconceptions in electric circuits. This non-probability sampling technique involves intentionally selecting individuals with specific characteristics that align with the research objectives (Cooksey & McDonald, 2019). Teachers were selected because they were currently responsible for teaching the topic of electric circuits in Grade 11 Physical Sciences, and were therefore well-positioned to share relevant classroom experiences, teaching strategies, and insights related to learner misconceptions.

A sample size of three Physical Science teachers, pseudo-named Mr. MT, Mr. NM and Ms. RM, together with their learners, was selected following the rationale that qualitative research does not necessitate large sample sizes. The three teachers were drawn from three different schools to allow for variation in teaching context. Such a small sample allows for detailed study and in-depth engagement with each participant, ensuring that the data collected is thorough and nuanced (Sandelowski, 1995 & Vasileiou, et al., 2018). The decision for this specific sample size was grounded in the understanding that it would enable the researcher to achieve saturation; that is, the point at which no new information emerges from data collection. The small, convenience sample limits generalisability and suggests that findings are exploratory.

3.6 DATA COLLECTION INSTRUMENTS

In this study, an open-ended questionnaire, individual semi-structured interviews, a content test and classroom observations during feedback were used to collect data.

3.6.1 Questionnaire for teachers

According to Mashuri et al. (2022), a questionnaire is a research instrument that consists of a set of questions or other types of prompts that aim to collect information from a respondent. For this study, I adapted questionnaire that had 10 items from a study by (Moodley & Gaigher, 2019). Question 1 and 4 were removed as they fell out of the Grade 11 syllabus. The questionnaire (Appendix 1) was then based on eight multiple-choice items. The questionnaire was used to ask, as Van der Merwe & Gaigher (2011) put it, 'questions about questions', where teachers were asked about questions suitable for learners. Each question started with a multiple-choice item suitable for learners, with distractors based on misconceptions. The teacher was not required to answer this question. Instead, the correct answer was provided, and the teacher was asked about the incorrect options s/he expects his/her learners to choose. This enabled me to probe the teachers' awareness of their learners' misconceptions about electric circuits.

The following Table 3.2 summarises misconceptions that were explored in the questionnaire (APPENDIX 1):

Table 2.2 :Summary of misconceptions explored in the questionnaire

Item	Misconception explored	Distracter representing the misconception
1	Attenuation model	B/C
2	Weakening current model	B/E
3	Clashing current model	B
4	Empirical rule model	C/E
5	Short circuit model	E
6	Voltage and current not distinguished	B

7	Sequential model	C
8	Power supply misconception OR Parallel circuit misconception.	B/C

3.6.2 Semi-structured interviews

The questionnaire was followed by the design of an interview schedule. An interview is a qualitative research technique that involves asking open-ended questions to respondents to collect data about a topic (Monday, 2020). The type of interview chosen for this study was a semi-structured interview. As stipulated in Low (2019), in a semi-structured interview, the researcher uses a combination of open-ended and closed-ended questions to gather detailed, qualitative data from participants while still maintaining some level of standardisation across interviews. The interview questions were inherently tied to the questionnaire's multiple-choice items, infused with a dual purpose – to garner a sense of the misconceptions teachers expected their learners to hold and to unfold their subsequent interventive approaches. The interview (Appendix 2) was face-to-face and was used to explore strategies proposed by teachers to address the misconceptions.

3.6.3 Conceptual understanding test for learners

A conceptual understanding test (Appendix 1) for learners was adapted from the teachers' questionnaire, serving a complementary role tailored specifically for learner assessment. Soeharto et al. (2019) describe a conceptual understanding test as a test that assesses a learner's understanding of a concept or their prior knowledge. For this study, the test was designed to engage learners actively and assess their grasp of the electric circuit concepts that are frequently misconstrued, as highlighted in the findings from the teachers' questionnaire. Each item in this test was modelled after the structure of the questionnaire, incorporating distractors that mirrored those misconceptions the teachers anticipated their learners would hold. While the questionnaire aimed at gauging teachers' perceptions and preparedness to address misconceptions, the conceptual understanding test directly measured the learners' conceptual knowledge and detected the same misconceptions from the learners' point of view. By employing a mirrored structure between the teacher questionnaire and the learner test, the study leveraged a cohesive assessment framework that aligns teacher insights with learner performance. This alignment not only illuminated the prevalence of misconceptions among learners but also facilitated a comparison between teacher expectations and actual learner understanding.

The development of this test was crucial for the efficacy of this study, as it provided a tangible measure of the impact of misconceptions on learning. The insights gleaned from the test results can serve as a powerful indicator for evaluating the validity of the teachers' predictions about their learners' misconceptions, thereby enriching the interpretive value of research findings. In administering the conceptual understanding test, the researcher ensures congruence with established objectives, allowing for a robust analysis of the acquired data. The test results were expected to contribute significantly to understanding the gap between teacher perceptions and learner understandings and guiding the development of targeted instructional strategies to improve conceptual understanding of the topic of electric circuits. The test results are excluded from this dissertation, but the teachers only marked them as a way of preparing the feedback session.

3.6.4 Lesson observations

Lesson observation, also known as classroom observation, is a practice in which a lesson is observed to assess the quality of teaching to ensure learners receive the most effective learning experience (O'Leary, 2020). For this study, observation sessions were used as a data collection instrument to examine the in-action strategies teachers used to provide feedback to learners following the conceptual understanding test that they wrote. The teachers provided feedback after having marked the test. Thus, it is assumed that the feedback was informed by their knowledge of misconceptions but also concrete evidence from the learners' test responses. These sessions were pivotal for understanding how teachers approached and addressed misconceptions about electric circuits directly with learners. These sessions were designed around specific criteria important for capturing the dynamics of feedback. Mainly the language used by teachers to communicate science concepts and correct the misconceptions, the types of misconceptions being challenged and the clarity of explanations given, non-verbal cues that may indicate learner confusion or understanding, and how teachers encouraged learners to think critically about their answers. These sessions were vitally important to the research objectives because they allowed me to gather direct evidence of pedagogical strategies and teacher interventions, thus offering a real-life context to the study. They also enabled me to analyse the actual interactions between teacher knowledge and learner understanding, providing insight into the effectiveness of various feedback techniques. Additionally, they allowed me to observe the immediate reactions of learners, thus offering clues as to the efficacy of the feedback for correcting misconceptions. By capturing these live interactions, the study gained a depth of understanding of teacher methodologies and learner responses that cannot be achieved through questionnaires or interviews alone. Observations are thus an invaluable tool for examining the practical application of theoretical knowledge in the classroom (O'Leary, 2020).

Through this methodological approach, the study aims to foster a comprehensive understanding of the intricate dynamics between teacher perceptions, learner misconceptions, and pedagogical interventions.

3.7 DATA COLLECTION PROCEDURES

Data was collected in a convenient setting for the participants. Reis (2018) describes the research setting as the physical, social, or experimental context in which a research study is conducted. For this study, the setting was each participating teacher’s school. Each participant was visited on five times during the data collection process. The first visit was to explain the study’s purpose, procedures, potential risks, and benefits as outlined in the participant information sheet (Appendix 3). Also, the visit included obtaining informed consent from participants for their involvement in the study and recording the data collection sessions. During the second visit, I distributed the conceptual understanding questionnaire to the teachers, allowing them to complete it at their convenience. This ensured a reflection of their genuine understanding and opinions. Once they completed the questionnaire, an interview session at their respective schools was scheduled.

During the third visit, semi-structured interviews were conducted by the researcher. These interviews were audio-recorded for accuracy in data capture. It was during this visit that a day was scheduled for teachers to administer the conceptual understanding test to their learners to assess their understanding of electric circuits. The test was scheduled during a regular class session to ensure a natural setting. The test was administered by the teacher in the absence of the researcher, and the test was marked by the teacher. Once the teacher participants were done marking, the researcher was invited to review the learners' responses to the conceptual understanding test and a feedback session was scheduled, where observations would be done. On the fifth and last visit to the participants' schools, lessons were observed during which the teachers were giving feedback to the learners. The feedback sessions were observed with a greater focus on the strategies used by teachers to address misconceptions. The sessions were an hour long in each school. The entire feedback sessions were video recorded to observe and capture non-verbal cues, classroom dynamics, and the interaction between the teachers and learners.

3.8 DATA ANALYSIS METHODS

The techniques and procedures for analysing the collected data were grounded in deductive content analysis. Deductive content analysis is a qualitative research method that uses previous knowledge to test theories, models, or hypotheses in a new context (Pandey, 2019). In this study, this approach was used to systematically evaluate the teachers' awareness of common learners' misconceptions and their planned strategies to address the misconceptions and enacted strategies during feedback sessions. I categorised the collected data according to the eight predefined misconceptions. The initial phase of data analysis reviewed the misconceptions anticipated by the teachers, and these were then compared to a coding framework developed from existing literature on documented common misconceptions in electric circuits. This enabled me to use deductive analysis to determine if teachers correctly predicted learners' misconceptions. From this, teachers' awareness was categorised as showed awareness or showed no awareness, based on the link between the teachers' predicted misconceptions and documented common misconceptions in literature.

The teachers' interviews about their planned strategies to address the misconceptions were transcribed (e.g. Appendix 4A - C) and subjected to deductive thematic analysis through the lens of the PCK framework, focused on three components: curricular saliency, looking at how teachers showed an ability to sequence and prioritise key ideas to address misconceptions, representations, focusing on the teachers' use or lack of use of models, analogies, simulations and visual aids to clarify abstract concepts, and conceptual teaching strategies to promote conceptual understanding employing inquiry-based learning and guided discussions. Choosing these three components was guided by the specific aim of the research, which was to explore teachers' awareness of learners' misconceptions about electric circuits and how they address them during feedback. Through this approach, the study was able to explore how the teachers' planning of lessons reflected their understanding of common learners' misconceptions as well as the influence their PCK had on their approach to addressing misconceptions. Relevant excerpts from the interview transcripts were selected and used to demonstrate the planned strategies and diagnostic activities.

The teachers' enacted strategies were then analysed through classroom observation videos of the feedback sessions, and the focus was on how they addressed the misconceptions in instantaneously. The analysis was through a deductive approach that was based on Scott et al.'s (2006) classification of Teacher talk, which differentiates between authoritative versus dialogic teacher talk, focusing on whether the teachers presented information unilaterally (classified as authoritative) or if they stimulated learners to express and revise their ideas (classified as dialogic), and interactive versus non-interactive teacher talk, which focuses on how the teachers engage with learners' responses (classified as interactive), or if they presented the information without the learners' input (classified as non-interactive). These dimensions allowed me to determine the extent to which the teachers fostered opportunities wherein learners were enabled to challenge and revise their misconceptions during the feedback sessions. The findings of the enacted approaches were then compared with the planned strategies to explore the coherence between planning and enactment.

3.9 MEASURES OF TRUSTWORTHINESS

Trustworthiness in qualitative research is a measure of the quality, authenticity, and truthfulness of its findings (Shufutinsky, 2020). As Adler (2022) postulated, it is important to ensure trustworthiness to establish the credibility and reliability of qualitative research, which explores human behaviour, attitudes, and experiences. To ensure trustworthiness in this study, I employed several measures to address validity, reliability, and transferability.

In addressing validity and credibility, I made use of triangulation. Triangulation is a qualitative research strategy that uses multiple methods or data sources to develop a comprehensive understanding of a phenomenon (Moon, 2019). Morgan (2019) asserts that triangulation can also be seen as a way to test validity by converging information from different sources. To achieve this, I compared the teachers' predicted misconceptions through a questionnaire, the teachers' interview responses, and their actual teaching approaches. This allowed the study to cross-verify the information to build a well-substantiated understanding of the phenomena being studied. In addition to this, I employed reflexivity. Kalu (2019) describes reflexivity as a critical approach in qualitative research that involves the researcher reflecting on their role in the research process and how their subjectivity and context influence the research. To achieve this, I documented my biases and assumptions and reflected on how these may affect the study. This included acknowledging my preconceptions and being transparent about methodological decisions.

To address transferability. This is a quality criterion that measures how applicable a study's findings are to other contexts, settings, or respondents Tuval-Mashiach (2021). I made use of rich, thick descriptions by providing detailed descriptions of the research context, sample, and findings. This will enable others to determine the extent to which the results may apply to different contexts.

3.10 ETHICAL CONSIDERATIONS

As a research institution, the University of South Africa (UNISA) has a set of ethical guidelines that must be followed by researchers. For this study, I took into account the following ethical issues: the participants in the study were adequately informed about the research and requested to provide their consent to partake(Appendix 8 and 9). Additionally, they were made aware of their freedom to leave the study at any moment. Participants' confidentiality was always protected by the study(Appendix 3). Their identities were not disclosed in any of the reports or publications related to the study. The participants had the choice to maintain their anonymity if they desired. They received an overview of the results and had the chance to ask any questions they had. Only the researcher has access to the data gathered for the study, which is kept in a safe place.

3.12 CHAPTER SUMMARY

This chapter detailed the research methodology and design that was used in the study. It outlined the qualitative case study approach and interpretivist paradigm, including the purposive sampling of the three participating teachers. It further details how questionnaires, interviews, learner tests, and lesson observations were used to collect the data. The chapter also shows how the study adopted a deductive thematic analysis to interpret the data through the lens of PCK and Teacher Talk frameworks. It also addressed ethical considerations and the trustworthiness of the study.

4. CHAPTER FOUR: AWARENESS OF MISCONCEPTIONS AND PLANNED STRATEGIES

4.1 INTRODUCTION

This chapter presents findings of teachers' awareness of their learners' misconceptions about electric circuits and the strategies they recommend for addressing the misconceptions. As indicated earlier, the teachers' awareness of the misconceptions was explored using a multiple-choice questionnaire whereby teachers were provided with the correct answers to each question and requested to indicate options that learners will most likely choose, with reasons. Strategies proposed for addressing the misconceptions were explored using interviews against the same misconceptions in the questionnaire.

The strategies proposed by the teachers to address the misconceptions are studied through the lens of Pedagogical Content Knowledge (PCK), a concept that has emerged to incorporate the specialised knowledge teachers require to make content accessible to learners (Gao, et al., 2021). This chapter focuses on the components of PCK as expressed in the grand rubric, which reflects a shared understanding among scholars who attended the second PCK summit (Chan et al., 2019). The grand rubric proposes the following components of PCK: Knowledge and skills related to (i) curricular saliency, (ii) representations and (iii) conceptual teaching strategies. The misconceptions constitute the components of learners' understanding of concepts. Hence, the analysis of the proposed strategies focused on whether the other components of PCK are used to address them. The components are described in detail below.

Curricular Saliency refers to the teacher's awareness of the most important concepts in the topic of interest, in this case electric circuits, and how they connect with concepts of other topics in the curriculum (Mavhunga, 2020). The component also includes the sequencing of concepts, moving from the known to the unknown (Mavhunga, 2020). **Representations** employ a variety of tools, models, and explanations to help learners comprehend and conceptualize abstract ideas (Abdurrahman & Setyaningsih, 2019). Finally, **Conceptual Teaching Strategies** are the approaches and techniques that teachers use to enhance deep understandings and rectify misconceptions, rather than only addressing surface-level errors (Moodley & Gaigher, 2019).

The findings of the study will be presented under the learners' misconceptions described in chapter 2. Teachers' selections of the options likely to be chosen by the learners are tabulated and then followed by their reasons for their choices. Thereafter, the strategies that they propose for addressing the misconceptions are described.

4.2 MISCONCEPTION EXPLORED IN QUESTION 1

The attenuation model was explored in question 1, which sought to probe whether teachers were aware that learners often believed that current or charge instead of energy is converted to light.

4.2.1 Teachers' awareness of the misconception

Table 4.1 below outlines the first question used to assess the attenuation model misconception. It also indicates teachers' selections of options that their learners are most likely to choose.

Table 3.1: Exploration of Question 1

Question 1 Why does a bulb light up when connected in a circuit? (A) Electrical energy is converted to light (B) Electrical charge is converted to light (C) Electrical current is converted to light (D) All of the above The correct answer is (A)		
Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
C	C	C

The correct answer is A, which indicates that electrical energy is converted to light. The distractor, C, was designed to be chosen by learners holding the 'attenuation model' misconception. All three teachers shared similar insights into why they believed learners would choose option C, which highlights a common misconception: that electric current, rather than electrical energy, is what gets converted into light. For example, Mr. MT pointed out that learners often assume it is the current that transforms into light because they typically do not connect energy with this process. He elaborated that learners might ignore the concept of energy altogether and instead concentrate on the current as the source of light. He remarked, ‘I think learners will think that electrical energy is the one that is converted to light…they will not think of energy.’

These teachers’ explanations confirm that they all understand the ‘attenuation model’ misconception.

4.2.2 Strategies for addressing the misconception

The three teachers share a common approach to addressing misconceptions about electric circuits. They focus on revisiting the basic energy, charges, and current definitions. By emphasising these foundational concepts, they effectively clarify important ideas and help students overcome misunderstandings related to energy conversion. However, while their verbal explanations are valuable, incorporating visual or interactive tools, such as interactive simulations, could significantly enhance students' understanding and engagement.

Mr. NM exemplifies this method by saying:

> *"I will use the definitions for electrical energy, electric charge, and electrical current. This way, I can explain what each term means and how they function in a circuit—so that learners can understand what makes the bulb light up."*

Ms. RM also emphasizes the importance of clarifying energy's role in circuits. She explains:

> *"When you plug in a circuit, students often think electricity flows directly to light the bulb. But really, it's the energy released by the battery that gets converted into light, not just the current."*

Mr. MT provides an even more detailed explanation, directly tackling this misconception. He states:

> *"Electrical energy can be converted into light or heat, but here we're focusing on light. It's electrical energy, not electrical current, that gets transformed into light."*

This clear distinction helps reinforce the correct understanding of energy transformation within a circuit, giving students a more accurate view of how these processes work.

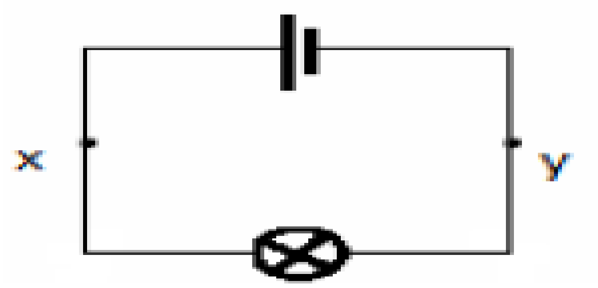
4.3 MISCONCEPTION EXPLORED IN QUESTION 2

The weakening current model was explored in question 2 which sought to probe whether teachers were aware that learners often believe that current gets used up and thus weakens in a series connection.

4.3.1 Teachers' awareness of the misconception

Table 4.2 below outlines the first question used to assess the weakening model misconception. It also indicates teachers' selections of options that their learners are most likely to choose.

Table 4.2: Exploration of Question 2

<table>
<tr><td colspan="3">Question 2
How do the currents at point x and y compare?


(A) x = y
(B) x > y
(C) y > x
(D) x = 0
(E) y = 0
The correct answer is (A)</td></tr>
<tr><td colspan="3">Which wrong option do you expect your learners to choose?</td></tr>
<tr><td>Mr. MT</td><td>Mr. NM</td><td>Ms. RM</td></tr>
<tr><td>B</td><td>B</td><td>C</td></tr>
</table>

The correct answer is A, which indicates that the current stays the same throughout the circuit. The distractor B was designed to be chosen by learners holding the 'weakening current' misconception.

Mr. MT and Mr. NM predicted that their learners would select distractor B, reflecting the misconception of a "weakening current." Mr. NM elaborated on this by explaining that learners might think some of the current is "used up" by the bulb. He stated:

> *"Current flowing from x is going to pass through the bulb, then when it has passed through the bulb, it means some of the current is going to remain at that bulb, and when it reaches y, it has been decreased."*

On the other hand, Ms. RM anticipated that her students would select distractor C, which is tied to a common misconception about current in a series circuit. However, her explanation centres on electron flow rather than conventional current. She elaborated:

> *"The reason for choosing option C was based on the fact that they know electrons move from a negative terminal to a positive terminal. So, they might think that Y is going to carry more of the electrons, resulting in X having fewer electrons."*

This insight highlights a misunderstanding related to how electron current behaves in the circuit, illustrating the challenges students face in grasping these concepts.

4.3.2 Teaching strategies for addressing the misconception

While the teachers' explanations are accurate, they lack interactive or visual strategies that could help learners gain a deeper understanding beyond simple memorization. Their approach tends to focus on the essential curriculum points, but there is little evidence of using visual aids or conceptual teaching methods. The explanations centre on the theoretical concept of current flow in a series circuit, consistently emphasizing that the current remains the same throughout a single path. For example, Mr. MT explains:

> *"The current is the same. As the current is moving, it is anticlockwise. So, the same current that is measured at point X is the same as the current measured at point Y."*

Similarly, Ms. RM adds:

> *"Since it is a single path from one end to another, the current that enters is the same. So everywhere, throughout the whole circuit, the current is the same in a series circuit."*

These verbal explanations do reinforce an important principle, but they may not fully address the conceptual challenges that learners encounter. Incorporating more engaging and interactive methods could help bridge this gap and support deeper learning.

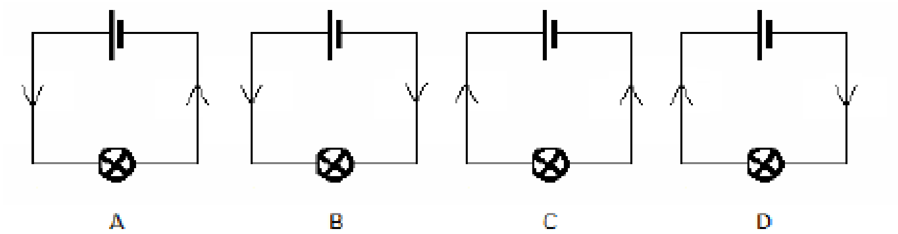
4.4 MISCONCEPTION EXPLORED IN QUESTION 3

The clashing currents misconception was explored in question 3, which inquired whether teachers are aware that many learners believe that current flows from both poles of the battery in opposite directions towards the resistor, creating 'clashing currents' that generate energy within the resistor. This incorrect understanding is referred to as the 'clashing current model'.

4.4.1 Teachers' awareness of the misconception

Table 4.3 below outlines the first question used to assess the clashing currents model misconception. It also indicates teachers' selections of options that their learners are most likely to choose.

Table 4.3: Exploration of Question 3

<table>
<tr><td colspan="3">Question 3
Which diagram correctly represents the flow of conventional current in the circuit?


The correct answer is (A)</td></tr>
<tr><td colspan="3">Which wrong option do you expect your learners to choose?</td></tr>
<tr><td>Mr. MT</td><td>Mr. NM</td><td>Ms. RM</td></tr>
<tr><td>D</td><td>D</td><td>D</td></tr>
</table>

The correct answer is A, indicating that conventional current flows from the battery's positive to negative terminals. Distractor B was designed to appeal to learners holding the 'clashing current' misconception. However, none of the teachers selected it. Instead, all teachers anticipated that their learners would select option D, which claims that conventional current flows from the battery's negative terminal to the positive one. While this answer is incorrect, it highlights a typical misunderstanding about current conventions rather than a deep-rooted misconception about how current actually flows. When asked why he believed his learners would choose this option, Mr. MT noted that learners might be influenced by the physical appearance of the terminals instead of established conventions:

> *"I think learners will choose option D because they will take it in the sense that current is flowing from the small terminal (negative) to [the] big terminal positive They will think maybe it is flowing from small terminal to big terminal."*

This insight shows that learners might interpret the direction of current flow based on the size of the terminals, mistakenly assuming a flow from negative to positive, which aligns more with electron flow than with conventional current. Interestingly, none of the teachers anticipated that learners would choose option B, which reflects the 'clashing current' misconception. This lack of expectation suggests that teachers may not be fully aware of certain misconceptions, like the clashing current model or the misconception may not be common in their classrooms.

4.4.2 Strategies for addressing the misconception.

All the teachers prioritize key curriculum points but often do so with little use of visual representations or conceptual teaching strategies. While they emphasise the conventional direction of current flow, their methods sometimes rely on simply telling learners the correct answers whilst they also tackle deeper conceptual conflicts, like the differences between currents.

For example, Mr. NM made an effort to incorporate a visual representation by using a physical battery to illustrate conventional current flow. He explains:

> *"I will take a battery because on the battery we have a positive side and also the negative side. I will introduce this conventional current by telling them that the current will be flowing from the positive to the negative. In the circuit, the big terminal represents the positive and the small terminal represents the negative."*

This approach helps learners visually connect the abstract concept of conventional current flow with the familiar layout of a battery, providing a practical reference point. Similarly, Ms. RM clarifies the distinction between electron flow and conventional current, addressing a common source of confusion. She states:

> *"I will mention that the one that moves from negative to positive is the electron. However, conventional current is the one that moves from the positive terminal to the negative terminal. That is why option D cannot be the correct answer."*

By explaining that "conventional current flows in the opposite direction to electron movement," Ms. RM offered learners a clear framework to understand these two different flows.

While all three teachers emphasised teaching correct scientific conventions, only Mr. NM's use of visual analogies and Ms. RM's focus on conceptual distinctions provide strategies that go beyond rote explanations. Although these approaches are somewhat limited, they do help reinforce learners' understanding of both electron movement and conventional current flow, effectively addressing some misconceptions.

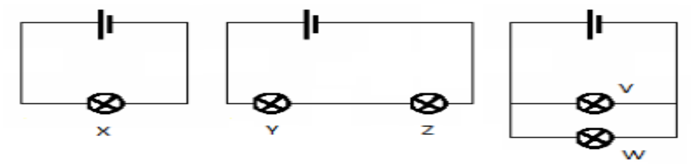
4.5 MISCONCEPTION EXPLORED IN QUESTION 4

The empirical rule model misconception was explored in question 4, which sought to determine whether teachers were aware that learners frequently believed that a light bulb farther from the battery would glow dimmer.

4.5.1 Teachers' awareness of the misconception

Table 4.4 below outlines the first question used to assess the empirical rule model misconception. It also indicates teachers' selections of options that their learners are most likely to choose.

Table 4.4: Exploration of Question 4

<table>
<tr><td colspan="3">Question 4
Which bulb or bulbs are the least bright?


(A) y, z
(B) y, z, v, w
(C) w
(D) x
(E) z and w
The correct answer is (A)</td></tr>
<tr><td colspan="3">Which wrong option do you expect your learners to choose?</td></tr>
<tr><td>Mr. MT</td><td>Mr. NM</td><td>Ms. RM</td></tr>
<tr><td>E</td><td>B</td><td>D</td></tr>
</table>

The correct answer, A, indicates that two bulbs connected in series were less bright than two identical bulbs connected in parallel or a single identical bulb. The distractors were designed to reflect the misconception: distractors C and E targeted learners who believed that a bulb farther away from the battery would glow dimmer. Only Mr. MT selected option E, which reflects a common misconception among learners. When asked why he thought his learners would be inclined to choose this answer, he explained,

> *"Since the current is flowing for bulbs y and z, learners will expect more current at y than at z, the same applies to the parallel connection, where learners think the current starts from v to w, and they expect the last bulb to be the least bright, leading them to believe that z and w will be the dimmest."*

This highlights a frequent misunderstanding: learners often think that current decreases as it flows through a circuit, causing bulbs that are farther from the battery to appear dimmer. Mr. MT's choice of option E shows that he was aware of this misconception and recognised that learners may mistakenly believe brightness depends on distance from the battery.

In contrast, Mr. NM chose answer B, which did not align with the misconception related to the “empirical rule model,” but rather addresses the “parallel circuit misconception.” When asked why he thought learners might select this answer, he explained,

> *“I think learners will choose option B because they might see that if there are more bulbs in the circuit, they will share all the volts available. So, they might think that all of them will be less bright.”*

This response indicates that Mr. NM was tackling the parallel circuit misconception, where learners would incorrectly believe that adding more parallel components increases resistance and reduces the brightness of each bulb due to a presumed division of voltage. While Mr. NM may not specifically recognize the empirical rule model misconception, his selection of option B suggests he understood another common misconception related to brightness in parallel circuits.

On the other hand, Ms. RM chose answer D, which suggests that a single bulb connected in a circuit would be the least bright. However, when asked why she thought her learners might choose this answer, she left the question unanswered. This lack of explanation limited my insight into her understanding of the misconception.

4.5.2 Strategies for addressing the misconception.

All three teachers prioritized important curriculum concepts, focusing on key ideas like voltage division, brightness, and the relationship between current and resistance in circuits. However, their teaching methods often lacked visual representations, such as circuit diagrams, and engaging strategies like analogies or hands-on experiments that could enhance learner understanding and involvement.

For instance, Mr. MT explained how voltage affects brightness in series circuits:

> *“For the first circuit, the voltage at point X is going to be the same because it only has one bulb. But in the second circuit, points Y and Z are connected in series, so they will divide the potential difference. When the potential difference is divided between Y and Z, they will be less bright because potential difference is directly proportional to energy.”*

Similarly, Mr. NM discussed how circuit configuration impacts bulb brightness:

> *"To explain to learners, I will use the series connection and the parallel connection so that they can understand how the brightness of the bulb depends on the configuration."*

Ms. RM focused on potential difference and brightness in parallel circuits:

> *"In a parallel circuit, both bulbs have the same voltage. According to Ohm's law, potential difference is directly proportional to current. So, if we have resistors connected in parallel, they will carry the same potential difference from the battery, resulting in higher brightness for the bulbs."*

Although their explanations are accurate, they could be made more engaging with teaching strategies that help learners grasp these concepts more effectively.

4.6 MISCONCEPTION EXPLORED IN QUESTION 5

Question 5 aimed to determine whether teachers were aware that learners often believe wires in a circuit without electrical devices can be ignored when analysing the circuit.

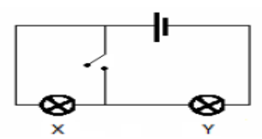
4.6.1 Teachers' awareness of the misconception

Table 4.5 below outlines the first question used to assess the short circuit model misconception. It also indicates teachers' selections of options that their learners are most likely to choose.

Table 4.5: Exploration of Question 5

<table>
<tr><td colspan="3">Question 5

How does the brightness of the light bulbs change if the switch is closed?


(A) y brighter, x = 0
(B) both brighter
(C) y = 0 , x = 0
(D) x brighter, y = 0
(E) no difference
The correct answer is (A)</td></tr>
<tr><td colspan="3">Which wrong option do you expect your learners to choose?</td></tr>
<tr><td>Mr. MT</td><td>Mr. NM</td><td>Ms. RM</td></tr>
<tr><td>B</td><td>E</td><td>B</td></tr>
</table>

The correct answer, A, indicates that a short circuit between the battery and light bulb x would bypass the bulb x, leaving only bulb y lit, making bulb y brighter. Distractor E was designed for learners who hold the ‘short circuit’ misconception.

Only Mr. NM chose answer E, which indicate that there is no difference in the brightness of the light bulbs. When asked why, he responded that his learners would choose this option, he said:

> *“I think the learners will choose option E, in a sense that bulb x and bulb y are of the same resistance and the current will be flowing through x and y is the same. Meaning they will have the same brightness. Because they will be sharing the same potential difference, because we are having two equal resistors. By assuming that they have equal resistance, there will be no difference in brightness.”*

Both Mr. MT and Ms. RM chose answer B, suggesting they believed learners would think both bulbs would brighten after a wire is connected across the battery and bulb x. When asked why he thought learners would select this answer, Mr. MT explained,

> *“I think they will see the two bulbs as being connected in series, where the current remains the same. They expect that the current at x and y will be identical because they are in series and the switch is now closed. In their minds, the current flowing at x must match the current at y. They might not recognize that the wire changes the circuit to a parallel configuration; instead, they see it as a single path and assume that if current enters, it should be the same at both points.”*

Ms. RM echoed this reasoning but added more context about learners’ likely misconceptions regarding circuit setups:

> *“Essentially, they will think both bulbs are connected in series. I believe this happens because learners often don’t realize that even though this circuit setup looks like it’s still in series, it’s actually parallel once the switch is closed. When they close the switch, they might not see that there are now two paths for the current to take, so they’ll probably continue to think of it as a single path. This understanding of parallel circuits can be tricky for them because visually, it still appears to be one circuit, leading them to assume that current is shared equally.”*

Both teachers’ explanations reveal their belief that learners struggle to interpret how closing the switch creates an alternative pathway for the current to flow. They suggest that learners may continue to view the circuit as a single loop, misjudging how current behaves across the bulbs once the connection changes. This misunderstanding may lead learners to incorrectly conclude that current is evenly distributed among the bulbs, failing to recognise the characteristics of a parallel circuit and how it affects brightness.

4.6.2 Strategies for addressing the misconception

While all three teachers provided accurate explanations and introduced valuable concepts, they primarily relied on verbal communication. This approach overlooks opportunities to incorporate visual aids, interactive tools, or practical demonstrations that could enhance learner understanding and make the material more engaging and accessible. However, their explanations bring attention to an important idea: when the circuit is closed, the current stops flowing through bulb X. This understanding is key to grasping how short circuits impact current flow and the brightness of the bulbs.

For example, Mr. MT explained the short circuit and its effect on potential difference:

> *"Since the circuit is connected in series, when it is closed, bulb Y will be brighter. The current will flow past point X and will no longer go there. The potential difference at Y will be the same as the potential difference at the battery. Since potential difference is directly proportional to energy, Y will be brighter because X is essentially creating a shorter circuit."*

Mr. NM described how closing the switch redirects current:

> *"When I close the switch, I'm blocking current from flowing to bulb X. As the current moves through the circuit, it encounters resistance at X, so all the current flows to bulb Y, making it bright because it receives the full voltage."*

Ms. RM highlighted how closing the switch creates an easier path for current:

> *"At first, we have a series circuit, but once we close the switch, we're cutting off one path and creating an easier route for the flow of current."*

While these teachers effectively address key concepts related to short circuits, their reliance on verbal explanations leaves room for improvement.

4.7 MISCONCEPTION EXPLORED IN QUESTION 6

Question 6 sought to determine whether teachers were aware that learners often fail to distinguish between voltage and current. Specifically, this question aimed to explore the 'voltage and current not distinguished' misconception.

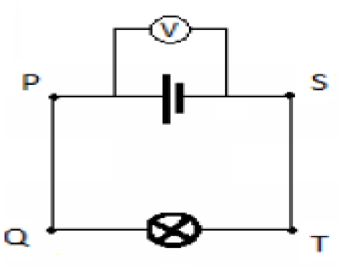
4.7.1 Teachers' awareness of the misconception

Table 4.6 below outlines the first question used to assess the parallel circuit misconception. It also indicates teachers' selections of options that their learners are most likely to choose.

Table 4.6: Exploration of Question 6

Question 6

A 6 V battery is connected to a bulb as shown above in the diagram. A voltmeter is the connected between P and S. Next it is connected between P and Q, then Q and T and finally T and S. what are the voltmeter readings between the various points?



	PS	PQ	QT	TS
(A)	6	0	6	0
(B)	6	6	6	6
(C)	6	2	2	2
(D)	6	3	0	3

The correct answer is (A)

Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
B	B	B

The correct answer is A. Distractor B was designed to attract learners who hold this misconception. All participants chose option B, showing that they might be aware of this misconception.

All three teachers (Mr. MT, Mr. NM, and Ms. RM) offered similar insights into why learners might choose option B on their test. They indicated that learners often think that voltage remains constant throughout the entire circuit. This confusion likely stems from learners mixing up the behaviour of voltage in parallel circuits with that in series circuits. Specifically, they tend to interpret voltmeter readings as indicating uniform voltage across the circuit, similar to how voltage remains constant across all branches in a parallel circuit.

Mr. MT succinctly captured this misconception by stating,

> *"Because the voltmeter is connected in parallel, and we know that in a parallel configuration, the potential difference remains the same. That's why they are selecting option B. They believe that if the potential difference from PS is 6 volts, then it must also be 6 volts at QP, QT, and even ST."*

The teachers' responses converge on the idea that learners mistakenly apply the rules of parallel circuits, where voltage remains consistent across branches to a series circuit, where voltage is divided among components. In a series circuit, voltage is not uniform; instead, it is distributed across components based on their resistance, with the full voltage only appearing across the battery. This misconception arises from learners' inability to distinguish between these two types of circuits, leading them to assume that voltage behaves similarly at all points, as it does in parallel circuits.

4.7.2 Strategies for addressing the misconception

The teachers' strategies for addressing learners' misconceptions about voltage distribution in circuits focus on important concepts but often lack sufficient visual representations and conceptual teaching methods. While each teacher aims to clarify how voltage readings should be interpreted across different parts of the circuit, their approaches primarily rely on verbal explanations, which may not fully address learners' deeper misunderstandings. For example, Mr. MT explains the expected voltage readings in a parallel circuit:

> *"When connected in parallel to the battery, the potential difference must measure 6 volts, which is the total voltage of the battery. From Q to T, it should also measure 6 volts because it's connected in parallel to the resistor. However, from P and Q, there won't be any reading because they aren't connected to either the battery or a resistor."*

Mr. NM emphasised the distinction between current and voltage:

> *"To help learners understand, I will define voltage and current and explain which one flows through the circuit. We know that only current flows, carrying voltage to the bulb. So, the only voltage that exists is at point QT."*

Similarly, Ms. RM described how to measure voltage across components:

> *"When we move from P to S, we measure the battery's voltage; moving from P to Q only measures the conductor, which is why it reads zero. From Q to T, we have a resistor that gives us a specific voltage."*

A key idea that comes through in their explanations is that voltmeters measure the potential difference between two points in a circuit. This is why the reading shows zero when there is no device, like a resistor or bulb, between those points to consume energy.

4.8 MISCONCEPTION EXPLORED IN QUESTION 7

This question explored the sequential model misconception, which aimed to determine whether teachers were aware that learners often believed that a change in the circuit would affect current in parts of the circuit located ‘ahead’ of the change, but not in parts located ‘behind’ it

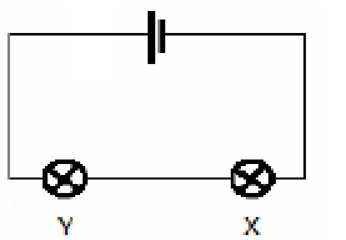
4.8.1 Teachers' awareness of the misconception

Table 4.7 below outlines the first question used to assess the sequential model misconception. It also indicates teachers’ selections of options that their learners are most likely to choose.

Table 4.7: Exploration of Question 7

<table>
<tr><td colspan="3">Question 7

What happens to the brightness of the bulbs X and Y if we add a resistor between them?

(A) X and Y both less bright
(B) X unchanged, Y less bright
(C) X less bright, Y unchanged
(D) X and Y both unchanged
The correct answer is (A)
</td></tr>
<tr><td colspan="3">Which wrong option do you expect your learners to choose?</td></tr>
<tr><td>Mr. MT</td><td>Mr. NM</td><td>Ms. RM</td></tr>
<tr><td>C</td><td>C</td><td>D</td></tr>
</table>

The correct answer, A, indicates that adding a resistor between two resistors connected in series would affect both resistors and make the bulbs less bright. Distractor C was designed to attract learners who hold the ‘sequential model’ misconception.

Both Mr. MT and Mr. NM provided similar explanations for why they believed learners would choose option C. They indicated that learners might mistakenly think that adding a resistor between points Y and X would affect the brightness of bulb X while leaving bulb Y unchanged. They suggested that learners likely assume the resistor would reduce the current reaching bulb X, while bulb Y remains unaffected due to its position in the circuit.

Mr. TM elaborated on this idea, saying,

> *"I think they will choose C because they believe that if a resistor is placed between Y and X, bulb X will be dimmer than bulb Y, or that Y will stay the same as current flows from Y to X. They might think that the current at Y changes before it reaches X, so the resistor decreases the current and makes X less bright."*

This explanation highlights a common misconception: learners often see the resistor as selectively reducing current only for the component after it, rather than understanding how current behaves throughout the entire circuit. Mr. TM's insight suggests that learners may not fully grasp the principles of series circuits and current continuity, yet neither he nor Mr. NM used visual aids or targeted strategies to address this misconception directly.

Ms. RM selected answer D, which incorrectly states that both bulb X and bulb Y would remain unchanged. When asked why she thought her learners might choose this option, she explained,

> *"I think it's D because of their understanding of electric circuits. They believe that in a series circuit, the current is the same everywhere, and if the current is constant, then the brightness will also be the same."*

This response suggests that Ms. RM did not think of the sequential model but rather thought of learners believing that just because the current is the same throughout, it remains unchanged if another resistor is added in series.

4.8.2 Strategies for addressing the misconception.

The teachers concentrate on important concepts related to voltage division and current distribution in series circuits, but they overlook the use of visual aids or conceptual teaching strategies. Their explanations focus on how potential difference and resistance affect current flow and brightness in series circuits, yet they miss opportunities to incorporate tools like diagrams or interactive models that could enhance learners' understanding. For instance, Mr. MT offers explains:

"Since this circuit is connected in series, we expect the potential difference to divide. If the total potential difference is 12 V, we expect to get 6 V across both X and Y. However, adding a resistor further divides the potential difference, making the components less bright."

Similarly, Ms. RM explains:

"When we add another bulb in a series circuit, we increase the resistance. Since resistance is inversely proportional to current, increasing resistance decreases current."

While these explanations are factually correct, they rely heavily on verbal communication and do not include visual aids or hands-on models that could help learners develop a deeper understanding

4.9 MISCONCEPTION EXPLORED IN QUESTION 8

Question 8 explored teachers' understanding of misconceptions related to power supply and parallel circuits.

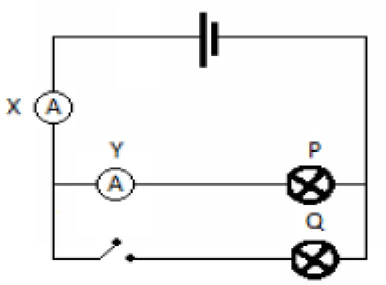
4.9.1 Teachers' awareness of the misconception

Table 4.8 below outlines the first question used to assess the sequential model misconception. It also indicates teachers' selections of options that their learners are most likely to choose.

Table 4.8: Exploration of Question 8

<table>
<tr><td colspan="3">Question 8

How do the readings on the ammeters X and Y change if the switch is closed?



(A) X increases, Y unchanged
(B) X unchanged, Y decreases
(C) X decreases, Y decreases
(D) X increases, Y decreases
The correct answer is (A)</td></tr>
<tr><td colspan="3">Which wrong option do you expect your learners to choose?</td></tr>
<tr><td>Mr. MT</td><td>Mr. NM</td><td>Ms. RM</td></tr>
<tr><td>C</td><td>D</td><td>D</td></tr>
</table>

The correct answer is A: adding a resistor in parallel decreases the total resistance of the circuit, thereby increasing the total current while not affecting the current through the initial resistor. Distractor C represents the common ‘parallel circuit’ misconception, where adding a resistor in parallel is thought to increase resistance and thus decrease the total current. Distractor B reflects the ‘power supply as a constant current source’ misconception, suggesting that adding a resistor in parallel diverts current away from the initial resistors.

Mr. MT selected answer C, indicating that he is aware of the “parallel circuit misconception,” where learners might believe that current decreases in one section of a parallel circuit due to current division. He explained,

> *“Since the circuit is going to be closed, I expect that they will think the current in X is going to decrease because X is connected to Q in series, where the current is the same. Since P and Q are connected in parallel, they expect the current to divide; the divided current at P is going to be the same as the one at Y.”*

On the other hand, both Mr. NM and Ms. RM chose answer D, suggesting they believed that adding a resistor in parallel increases the circuit’s total current while decreasing the current in the parallel branch. This indicates that they may not fully recognise the common misconceptions associated with the current division in parallel circuits. Mr. NM reasoned,

> *“I think the current in Y will be shared with bulb Q, which results in a decrease in the original current at Y. This also affects ammeter X, causing it to increase.”*

Similarly, Ms. RM explained,

> *“I chose D because they will think that when we had a series circuit, closing the switch opens up a different path. They might say that one in series is going to increase, but then when it gets to this point, it’s going to split. That’s why they might think that now, because of the division, it’s going to decrease. So I’m saying they will choose D because they believe one is increasing while this one is decreasing since we have parallel as a current divider.”*

These explanations highlight that while Mr. MT demonstrated an awareness of misconceptions related to parallel circuits and current division, both Mr. NM and Ms. RM may not have fully recognised these patterns of misunderstanding. Their responses suggest a focus on basic circuit mechanics, indicating an understanding rooted more in general circuit behaviour than in addressing specific learner misconceptions about how current divides in parallel branches.

4.9.2 Strategies for addressing the misconception.

The teachers focused on key concepts to address misconceptions about voltage division and current distribution in series circuits, but they missed the opportunity to use visual aids or conceptual teaching methods. Each teacher explained principles such as parallel and series configurations and the effects of resistance. For example, Mr. MT discussed how the current was affected when resistors were added in parallel:

> *"When the switch is closed, the current at Y will remain unchanged, while the current at X will increase because we are adding more resistors in parallel."*

Similarly, Mr. NM used Ohm's law to explain the relationship between resistance and current:

> *"As the total resistance of the circuit increases, the current will decrease."*

Ms. RM also explained important concepts, such as the impact of adding a bulb in parallel on voltage and current:

> *"In a series circuit, the total potential difference from the battery remains the same across the resistor, resulting in the same current at point Y."*

Although the teachers demonstrated a solid grasp of their content, their strategies mainly consisted of direct explanations, missing chances to integrate visual aids or interactive models. This reliance on factual information may lead learners to memorise concepts rather than develop a deeper understanding.

4.10 SUMMARY

This chapter presented findings on teachers' awareness of learners' misconceptions in electric circuits and their planned strategies to address them. Data from both questionnaires and interviews were used to analyse the findings, which revealed that while teachers were generally aware of learners' misconceptions, their explanations often lacked depth. The lens of the PCK framework was used to analyse the teachers' planned strategies, and the focus was mainly on curricular saliency, use of representations, and conceptual teaching strategies. The findings of the study showed variability in the teachers' planned strategies to address the learners' misconceptions, with some of them relying mainly on procedural methods instead of conceptual understanding.

5. CHAPTER FIVE: ENACTED STRATEGIES DURING FEEDBACK

5.1 INTRODUCTION

This chapter presents and analyses the data collected through classroom observations, specifically focusing on each teacher's feedback on learners' misconceptions in electric circuits during test sessions. The test was administered to learners and marked by the teachers, whose enacted strategies were examined through the lens of teacher talks as outlined by Mortimer and Scott (2003). The analysis of the feedback sessions was based on the key components of teacher talk: (i) authoritative or dialogic talk, and (ii) interactive or non-interactive talk. This chapter addresses the third secondary question: How do teachers address misconceptions in electric circuits when giving feedback to learners? As in the previous chapter, the analysis is organised by question, with a focus on misconceptions explored and how each teacher attempted to address them.

5.2 TEACHERS' STRATEGIES FOR ADDRESSING MISCONCEPTIONS FROM QUESTION 1

The attenuation model was explored in question 1, which sought to probe whether teachers were aware that learners often believed that current or charge instead of energy is converted to light.

Question 1 Why does a bulb light up when connected in a circuit? (E) Electrical energy is converted to light (F) Electrical charge is converted to light (G) Electrical current is converted to light (H) All of the above The correct answer is (A)		
Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
C	C	C

All the three teachers predicted that their learners would choose option C as the correct answer to question 1, which lighted a common misconception that electric current, rather than electrical energy, is what gets converted into light. When asked why they thought that their learners were likely to choose option C, they indicated that their learners often assumed that it is current that gets converted into light, not energy.

5.2.1 Mr. MT's strategies for addressing misconceptions in question 1

Mr. MT's strategy appeared non-interactive and authoritative because he provided the correct answer without further exploring learners' reasoning or misconceptions. For instance, he started the interaction by telling the learners that the correct answer was option A:

> ***Teacher:*** *the correct answer is letter A. Ke gore, …(meaning), the electrical energy aker (asking learners to confirm), according to the options that we have been given, it can only be converted to what? To…. Electrical energy can only be converted to what? [Learners: To ligt]*
>
> *teacher: to light aker? [Learners: Yeah…]*
>
> *teacher: but electrical charge, cannot be converted to….*
>
> *Learner: to light.*
>
> *teacher: or electrical current cannot be converted to light. The correct option is option A. where the electrical energy is converted to light*

The teacher did not explore learners' reasoning for choosing option A, nor did he consider any other options learners may have chosen based on their preconceptions of what gets converted into light when bulbs are connected in electric circuits. This approach did not challenge or clarify learners' misconceptions. The teacher simply told learners the correct answer without using any strategy to uncover and address misconceptions.

5.2.2 Mr. NM's strategies for addressing misconceptions in question 1

Mr. NM adopted a more interactive and dialogic approach. He dynamically involved his learners in a discussion and used targeted questioning to expose other possible misconceptions in addition to the more common one explored through option C and clarify concepts. He started by suggesting that option D was correct and then asked those that chose the option to support it with reasons. The reasons of the learners varied, including that charge, current and energy are similar (learner 1).

> *Learner 3: it cannot be possible that electrical charge be converted to light, it is only possible to convert electrical energy into light.*
>
> *Teacher: okay, so meaning that the correct answer there must be what? [Learners: (in unison), letter A?]*
>
> *Teacher: The letter A, energy can be converted into light.*
>
> *Learner 4: why sir do we say energy can be converted into light? Because, according to my knowledge, I chose C.*
>
> *Teacher: C is a current that is converted into light.*

Learner 4: when we start talking about circuits, it is current that flows.

Teacher: Current is flowing, flowing carrying what? [Learners: energy]

Learner 4's reasoning shows a misunderstanding between the concepts of current and energy in an electric circuit. The idea that current is converted into light indicates a misperception about the role that electric current (flow of electric charge) plays in the transfer of electric energy (work done by electric charge to produce light). This displayed the misconception that the teacher predicted that learners might have, hence, they would choose option C as the correct answer (Learner 4). By questioning learners about their reasoning and guiding them through discussions, he encouraged his learners to reflect on their misconceptions and correct their understanding. This approach proved to be effective in promoting critical thinking and addressing misconceptions through dialogue.

5.2.3 Ms. RM's strategies for addressing misconceptions in question 1

Ms. RM used a strategy that was highly dialogic and interactive. She engaged her learners in reflective questioning, allowing misconceptions to surface naturally. During the interaction, the learners presented varied responses that suggested widespread confusion among them about what is converted into light when a bulb is connected in an electric circuit. The presence of multiple incorrect answers indicated that learners may not have yet developed a strong foundational understanding of electrical energy conversion in an electric circuit.

She avoided correcting the learners immediately; instead, she allowed their reasoning to surface, thus creating an opportunity to diagnose misconceptions before guiding the learners towards the correct understanding. She began by asking those who chose option D to give the reason for their choice, to which a learner indicated that they chose option D because it said, all of the above. The learners' choice of option D (All of the above) suggested a lack of conceptual clarity concerning what gets converted into light. He might have just chosen a 'safe option', assuming that multiple concepts contribute to light production in electric circuits. Ms. RM did not immediately correct the wrong answer; she instead requested the learner to explain his reasoning, thus exposing the misconceptions and providing a point of departure for conceptual clarification.

Ms. RM challenged mistaken reasoning with targeted questions that encouraged critical thinking and pushed learners to differentiate between an electric charge (a physical quantity), the current (the flow of charge), and the electric energy (that which is converted into light). Ms. RM then directly corrected the misconception:

Learner 1: isn't that current if like the flow of charge, so that charge flows, as if like energy.

Teacher: no the movement of charge, result in or causes energy, charge is not energy. Does it make sense? [Learners: yes]

Teacher: Charge is not… [Learners: …energy]

teacher: alright, let us say, what is the law of conservation of energy?

Learners: energy cannot be created or destroyed. [Teacher: but]

Learners: can be converted from one form to another.

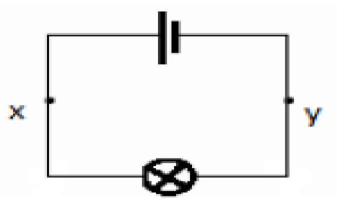
The teacher's statement that 'the movement of charge result in or causes energy' aided learners in understanding that charge is not transformed but transports energy, which is the one converted into light at the light bulb. She then connected the concept to the principle of conservation of energy by asking the learners to recall and apply their prior knowledge of this principle, and this proved to be an effective strategy as learners were able to state the law correctly. And, as a result, the teacher was able to lead them towards realising their mistake; instead of just telling them the correct answer, she reinforced the key takeaway, that it is energy, not electric current or charge, that is converted to light.

5.3 TEACHERS' STRATEGIES FOR ADDRESSING MISCONCEPTIONS FROM QUESTION 2

The weakening current model was explored in question 2, which sought to probe whether teachers were aware that learners often believe that current gets used up and thus weakens in a series connection.

Question 2

How do the currents at point x and y compare?



(F) x = y
(G) x > y
(H) y > x

(I) x = 0 (J) y = 0 The correct answer is (A)		
Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
B	B	C

Both Mr. MT and Mr. NM predicted that their learners would choose option B, which reflected the misconception of a "weakening current." They indicated that they thought their learners might think that some of the current is "used up" by the bulb. Whilst Ms. RM expected her learners to select option C, which is tied to electronic current flow in series circuits. She reasoned that her learners would know that electrons flow from negative to positive terminals and they might think that electrons would decrease as they move from Y to X.

5.3.1 Mr. MT's strategies for addressing misconceptions in question 2

Mr. MT's approach in addressing misconceptions explored by question 2 was authoritative and non-interactive because he started by simply confirming with learners the correct answer (Option A). He did not delve into the learners' reasoning for choosing option A, neither did he consider the learners who could have chosen different options. He did successfully guide learners to recognise that option A was the correct answer and reinforced the principle that current remains the same at different points in a series circuit:

Teacher: the correct answer is letter? … [Learners: A]

Teacher: Letter A aker? If you can check how do the currents at point x and y compare, aker? [Learners: yes]

Teacher: let's check that circuit, let's check the current at point x and at point y. and let's compare them. If you can check, the current will be flowing from which to which point? From y to x, aker? Then the current is going to be the same aker? Where x is equal to …. [Learners: y.]

By not exploring misconceptions, such as the idea that current decreases as it moves through the circuit (option B), Mr. MT missed an opportunity to address and correct these misconceptions. His approach did not have interactive questioning, and this could have provided with valuable insight into his leaners' misconceptions and helped him in addressing them.

5.3.1 Mr. NM's strategies for addressing misconceptions in question 2

Mr. NM's strategy was dialogic and interactive in that he prompted his learners to explain their reasoning for choosing option A as the correct answer. By encouraging learners to discuss why they selected the correct answer, the teacher started a dialogue that reinforced the concept of current in series circuit connections:

> *Teacher: Great! But can someone explain why it's A?*
>
> *Learners: Because X and Y are connected in series.*
>
> *Teacher: So that means the current is the same at both points?...... [Learners: Yes.]*
>
> *Teacher: Right! ….. The correct answer is A because the current flowing through X, after passing through the bulb, is equal to what…? [Learners: Y.]*

Although his questioning helped learners arrive at the correct answer, he did not explore the potential misconception that the current 'weakens' as it moves through the circuit (option B). Despite having predicted this misconception in the interview, he focused solely on confirming the correct answer without further exploration into the reasoning of learners who might have held this misconception. This lack of further interaction made him miss the opportunity to uncover and address the "weakening current" misconception.

5.3.2 Ms. RM's strategies for addressing misconceptions in question 2

Ms. RM's approach was dialogic and interactive, as she began by asking learners who chose incorrect options to provide reasons for their choice, thus uncovering their misunderstandings. For instance, when Learner 1 indicated that they chose option B, which suggested that they held the 'weakening current' misconception, the teacher asked the learner for a reason and the learner said that she thought that when current moves, it passes point X first before going to point Y, then the current would decrease when it passes X.

Ms. RM guided the learner to recognise that they are working with a series circuit by asking the other learners the kind of connection the circuit was:

> Learner 1: when the current moves, it pass x first before it goes to y. doesn't the current decrease when it passes x?
>
> Teacher: let us check, what kind of connection do we have?.......[Learners: series]
>
> Teacher: what happens to current in a series circuit? ….. [Learners: is the same.]
>
> Teacher: then if it is the same…. Learner 1, says when it enters x, the current decreases, meaning x will have more current than y.

> Learner 2: he didn't see It correctly
>
> Teacher: he thought x will take more current than y. now the question is what happens in a series circuit in terms of the current? the current is the same throughout the whole circuit. …….[Learners: yes]
>
> Teacher: so this means that this current, the moment it moves, from the side of x, it will be the same throughout the whole conductor. Does it make sense? ….. [Learners: yes]

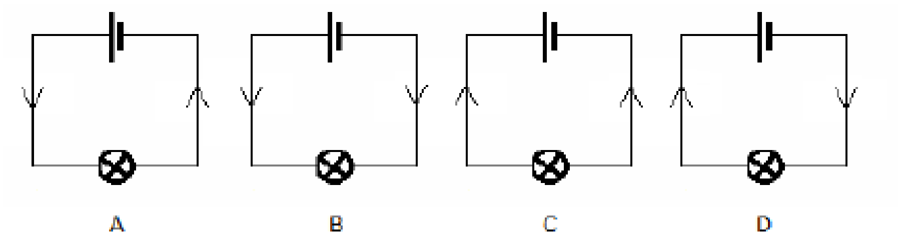
This approach was interactive because it involved the whole class in correcting the misconception, with the teacher using multiple prompts to guide the learners towards the correct understanding. Ms. RM was able to clarify Learner 1's error effectively by addressing his misconception directly and explaining that the current remains constant in a series circuit.

5.4 Teachers' strategies for addressing misconceptions from Question 3

The clashing currents misconception was explored in question 3, which inquired whether teachers are aware that many learners believe that current flows from both poles of the battery in opposite directions towards the resistor, creating 'clashing currents' that generate energy within the resistor.

Question 3

Which diagram correctly represents the flow of conventional current in the circuit?



The correct answer is (A)

Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
D	D	D

All teachers predicted that their learners might choose option D, which indicated that the learners might confuse conventional current and the flow of electrons. Interestingly, none of the teachers anticipated their learners to choose option B, which reflected the 'clashing currents' misconception. This suggested that the teachers might be unaware of the misconception, or the misconception is not common in their classrooms.

5.4.1 Mr. MT's strategies for addressing misconceptions in question 3

Mr. MT's approach to addressing misconceptions explored in question 3 was authoritative and non-interactive. Even though he predicted that his learners might confuse the flow of electrons with the flow of conventional current, when he gave feedback, he did not explore the actual presence of this misconception. Instead, he continued to focus on confirming the correct answer (option A). He did not explore any differing views held by the learners, instead, he began the interaction by telling the learners that the question was about the representation of the flow of conventional current and then proceeded to ask the learners what the correct answer was. And, because he already told them that the correct answer for all the questions is option A, the learners confirmed that the answer was A

Teacher: the correct answer there is option ……[Learners: option A]

Teacher: it is option A, because the conventional current is always moving from positive to negative. If you can check option A, it is moving positive to negative, or in an anticlockwise direction. But if you can check option B, they all moving in the same direction, option C they are all moving in the same direction, then option D they are all moving in different direction but in a clockwise direction.

By simply restating that the conventional current flows from the positive to the negative terminal, the teacher missed an opportunity to explore the learners' understanding and misconceptions, such as the idea of "clashing currents" (option B) where learners might be thinking that currents move in opposite directions and "clash" at the resistor. His approach involved confirming the correct answer, but did not open up space for interaction or further questioning that could have helped under and address misconceptions.

5.4.2 Mr. NM's strategies for addressing misconceptions in question 3

Mr. NM approached this question in a dialogic and interactive manner. He started the interaction by prompting the learners to identify the correct answer and then led them through a logical reasoning process by connecting the current flow to the battery's polarity. The teacher asked the learners targeted question to help them understand that conventional current flows from the positive terminal to the negative terminal of the battery:

Teacher: so, meaning that for us to be able to determine the correct answer, we look at the terminals of the cell? ….[Learners: yes]

Teacher: the big terminal, is it positive or negative? … [Learners: positive.]

Teacher: then the small terminal is what?......[Learners: negative.]

Teacher: meaning that it flows from big terminal to small terminal.

This reinforced the importance of battery polarity in determining current flow. The learners were enabled to connect conventional current flow to the battery's polarity by this scaffolded questioning approach. While Mr. NM was able to help learners establish that current flows from positive to negative, he did not help them distinguish between conventional current flow and electron flow. Mr. NM could have encouraged further enquiry by asking learners to analyse why the other options were incorrect and what would happen if the battery terminals were swapped. This would have allowed the learners to engage with the concept more thoroughly and clear up any outstanding confusion about the flow of conventional current.

5.4.3 Ms. RM's strategies for addressing misconceptions in question 3

Ms. RM used a dialogic and interactive approach when she started by prompting her learners for the correct answer and then encouraged them to explain their reasoning for choosing option A as the correct answer. This approach encouraged learners to express their reasoning and helped the teacher expose possible misconceptions about conventional current flow. When Learner 1 stated that the current moves from left to right, Ms. RM challenged this reasoning by asking, "Then what if we swap the terminals, is the current still moving left to right?", to which the learners responded, "no". This forced the learners to reevaluate their understanding and recognise that current flow is determined by battery polarity, not spatial orientation. So, to reinforce the correct concept, the teacher used guided questioning to help learners correct themselves:

> Teacher: so let's put it correctly. It moves from…? [Learners: positive to negative]
>
> Teacher: is that clear?...... [Learners: yes]
>
> Teacher: do not say left to right. We know that conventional current moves from positive terminal to negative terminal.

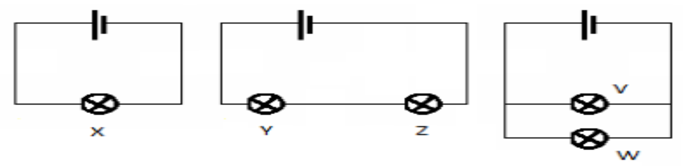
In this way, the teacher was able to reinforce the conventional current flow in a structured manner, and this made it easier for learners to adopt. The statement that "conventional current moves from the positive terminal to the negative terminal," helped the teacher break their learners' reliance on spatial cues and encouraged them to use scientific principles to justify their answers. However, Ms. RM did not address the confusion of electron flow. She could have strengthened her approach by asking whether the learners understood that electrons move from the negative to the positive terminal and why the conventional current model is used. Additionally, comparing the answer options (Why option B and D are incorrect) could have deepened learners' understanding and allowed them to better recognise the correct answer.

5.5 Teachers' strategies for addressing misconceptions from Question 4

The empirical rule model misconception was explored in question 4, which sought to determine whether teachers were aware that learners frequently believe that a light bulb farther from the battery would glow dimmer.

Question 4

Which bulb or bulbs are the least bright?



(F) y, z
(G) y, z, v, w
(H) w
(I) x
(J) z and w

The correct answer is (A)

Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
E	B	D

Only Mr. MT selected option E, which reflected a common misconception among learners, and he indicated that his learners might think that current decreased as it flows through a circuit, causing bulbs that a farther from the battery to appear dimmer. Whilst Mr. NM chose predicted that his learners would choose option B, which displays the "parallel circuit" misconception. And Ms. RM chose option D.

5.5.1 Mr. MT's strategies for addressing misconceptions in question 4

Mr. MT employed an authoritative and non-interactive approach to address misconceptions explored in question 4. He started by confirming the correct answer (option A) and then proceeded to explain the reasoning behind it. However, he did not ask learners who chose incorrect options to explain their reasoning, missing the opportunity to address any misconceptions they might hold.

> *Teacher: which bulb or bulbs are the least bright? We are looking for the ones that are the least bright. Is it x, y, z, v or w. The correct answer is …. [Learners: A]*
>
> *Teachers: it's A right? The least bright bulbs are y and z, why are we saying y and z? if we can check, we can also test it using the formula, I = V/R, because the resistors, in the second one, how are they connected?, they are connected in what? In series, right? Then we are going to have the total resistance resistance, right? Then where we divide with a bigger number, obviously we are going to have a what? A less current. Then the bulbs are least bright.*

Mr. MT dominated the discussion and asked the learners only confirmation-based questions, which prevented learners from actively reasoning, as they just responded with one-word confirmations instead of engaging in conceptual discussions over their choice of answers. A more interactive and dialogic approach could have involved asking the learners why they thought a particular bulb was the least bright and challenging their reasoning to uncover and address any misconceptions.

5.5.2 Mr. NM's strategies for addressing misconceptions in question 4

Mr. NM used an interactive and dialogic approach because he encouraged learners to explain their reasoning for the correct answer and engage in a critical analysis of the circuit diagrams. He asked learners to think about the connections in the circuit, especially the series and parallel connections, and to explain why bulbs in series are less bright due the division of voltage.

> *Teacher: so now the question is, which bulb or bulbs are least bright? What do we mean by least bright? …………[Learners: are not bright clearly]*
>
> *Teacher: are a little dim, right?......... [Learners: yes.]*
>
> *teacher: meaning that they are not receiving enough energy. Isn't it that we know that energy is the one that cause the bulb to what? to light up. Meaning that now they are receiving less energy. Do you understand it now? ……………[Learners: yes]*
>
> *teacher: are potential dividers, because if for example, if the battery was 12 v, for circuit A, this bulb was going to receive the whole 12 V but for B, the 12 V is going to be divided meaning their brightness will be lower and for C because it is in parallel, we know they are receiving the same voltage. Is it clear?......[Learners: yes]*

Mr. NM's approach to this question was highly interactive and encouraged critical thinking. However, he did not directly address the misconception held by Learner 2, who suggested that bulbs in series "share current." While Mr. NM continued the discussion, he missed an opportunity to address this misconception and could have asked targeted questions to clarify that in a series circuit connection, the current remains the same, and voltage is divided among the bulbs. His approach focused on energy transfer and voltage distribution, but could have benefited from more explicit comparisons of the brightness of bulbs in series and parallel to address the misconception he predicted (option B).

5.5.3 Ms. RM's strategies for addressing misconceptions in question 4

Ms. RM used a dialogic and interactive approach to actively engage her learners in the process of analysing the circuit diagrams and discussing the behaviour of current and voltage. She began by breaking down the concept of voltage distribution in series circuits and then used guided questioning to help learners understand that when multiple bulbs are connected in series, the current stays the same, but the voltage is divided among the bulbs:

Teacher: on circuit 2, we have two resistors, if they are two, the potential difference is divided among the two bulbs but current stays the same. And the last diagram is the parallel circuit, potential difference at v is the same as w, because it is what…? ……[Learners: parallel circuit]

Teacher: does it make sense?........ [Learners: yes]

Teacher: if that is the case, let us see, when you look at x, x is going to carryout the same voltage, neh? and Ohm's law says…

Learners: potential difference is directly proportional to the current

Teacher: meaning if we have a higher voltage , we have a higher………[Learners: current]

Teacher: in second diagram, at w and z, voltage will not be the same. So the answer the becomes y and z, because of lesser current.

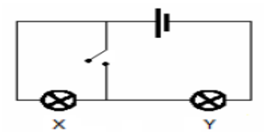
During the interaction, she realised that one learner misunderstood the relationship between voltage and bulbs in series and took the time to re-explain the concept. She helped the learners make connections between voltage and current in the circuit using Ohm's. However, Ms. RM's explanation that "X carries out the same voltage" might have led to confusion, as voltage exists as a difference between two points, not as something carried by a point.

5.6 Teachers' strategies for addressing misconceptions from Question 5

Question 5 aimed to determine whether teachers were aware that learners often believed wires in a circuit without electrical devices can be ignored when analysing the circuit.

Question 5

How does the brightness of the light bulbs change if the switch is closed?



(F) y brighter, x = 0
(G) both brighter
(H) y = 0 , x = 0
(I) x brighter, y = 0
(J) no difference

The correct answer is (A)

Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
B	E	B

Both Mr. MT and Ms. RM chose option B, this suggested that they believed that their learners might thought that both bulbs would stay bright after a wire is connected across the battery and bulb X. And only Mr. NM predicted that his learners might choose option E, indicating that they held the 'short circuit' misconception.

5.6.1 Mr. MT's strategies for addressing misconceptions in question 5

Mr. MT employed a non-interactive and authoritative approach in addressing misconceptions explored in question 5. He confirmed that the correct answer was option A without allowing learners to explain or justify their reasoning, and he dismissed their protests when they disagreed with him. Instead of diagnosing the possible misconceptions that his learners might have had, such as whether they thought the switch affected the entire circuit or whether they assumed that bulb X would still have some brightness, Mr. MT simply reaffirmed the correct answer:

> *Teacher: how do the brightness of the light bulbs change if the switch is closed. The correct answer is letter A. ansara ka moka ke letter A mo…. (all answers are letter A here).*
>
> *Learners: aowa… (protesting ….no)*
>
> *Teacher: the correct answer is letter A. then it says y brighter and x is what? It is zero. Let's check how the current is going to flow. We said it flows in an anticlockwise direction. If you can check from y, then we have our cell there, then if before we get to x, then the switch is open, that means we are not going to have a what, x is going to be zero. There is no current at x.*

His explanation, even though it directed the learners towards the correct answer, ended at a superficial level, wherein the learners became passive recipients of the information. The teacher's approach discouraged deeper learner engagement and hindered their critical thinking or considering any alternative explanations. When the learners protested the answer, which might have indicated that they held alternative concepts about the current flow, but instead of diagnosing their reasoning behind this, Mr. MT just reaffirmed the correct answer without addressing their confusion. The teacher could have first let the learners choose the answer and justify their answers before confirming the correct answer. To address their protest, he could have asked them why they disagreed and then used directed questioning to identify their misconceptions. Questions like whether they think the current is shared or whether they thought X would still have some brightness would have helped him diagnose the misconceptions his learners held.

Additionally, drawing a circuit diagram on the board and helping learners trace the current path before and after the switch would have helped reinforce why X went to zero brightness and why Y increased. Also, while Mr. MT in his explanation mentioned the anticlockwise current flow, he did not link this to how resistance or potential difference affects brightness in parallel and series circuits. He could have asked probing questions like why Y gets brighter, what effect closing the switch has on the total resistance of the circuit and what that says about brightness at bulb Y.

5.6.2 Mr. NM's strategies for addressing misconceptions in question 5

Mr. NM approached this question interactively and dialogically. He started by drawing the circuit board of question 5 as it appears on the test paper. Then, he asked his learners what the correct answer was and why. Interestingly, when he asked whether the correct answer was option E, which he predicted they would choose, they said no. This might have meant that none of his learners held the misconception he thought they might have.

> *Learner 2: sir, it is going to be B, because, at the moment, we have not closed the switch, both of them are dim, then once we closed the switch, both of them, each one gets its own current.*
>
> *Learner 3: so there is no difference, because they are connected in series, they are in series with each other.*
>
> *Teacher: but now we close the switch….[Learner 3: oh, y is going to be brighter.]….. [Learner 4: why?]*
>
> *Learner 3: because when current moves from a big terminal, and goes to the first junction, it will divide, and one goes to x and the other goes to x and the other goes to the switch.*
>
> *Teacher: we can hear it even if it is not correct. Let us check what is happen if we close the switch to the circuit. so it means that at first I was having this whole circuit with the switch open. Now I am closing my switch, when I close the switch I create what we call a short circuit. meaning I will only be having a circuit of y, because my current when it reaches the junction it won't go to x because the x branch has a high resistance and therefore the current will only flow through the switch branch to y.*

The teacher did not immediately dismiss incorrect answers, he instead asked his learners to explain their reasoning, which promoted active engagement and critical thinking that allowed misconceptions to surface for correction. Also, instead of providing an immediate correction, he allowed other learners to respond to the misconceptions. This spoke to the idea that peer explanations may sometimes be more effective than teacher explanations because learners are more likely to relate better to explanations from their peers (Pruthi, et al., 2022).

The view by Learner 2 uncovered a misconception wherein the learner held the view that once the switch was closed, each bulb would get its current. Another learner (Learner 3) showed the existence of a misconception wherein the learner held the idea that there was no difference in brightness between the two bulbs because they were connected in series. To address the revealed misconceptions, Mr. NM effectively introduced the concept of a short circuit, explaining how closing the switch created a lower resistance path, causing current to bypass bulb X and only flow through bulb Y.

5.6.3 Ms. RM's strategies for addressing misconceptions in question 5

For misconceptions explored by question 5, even though Ms. RM's approach included some interactive elements, it leaned more toward an authoritative-interactive style rather than fully engaging in open-ended dialogic teaching. Throughout the interaction, she explicitly checked for learners who might have held the misconception represented by option B, as she had predicted. Instead, she started by asking for learners who chose option C, representing the idea that both bulbs would have zero brightness when the switch was closed. One learner (Learner 1) indicated that he chose option C, his reason was, "because we use the switch to switch them on or off". In response to this reason, Ms. RM indicated to the learners that when the switch was open, current flowed through both bulbs, and it would not flow through the path where the switch was open.

Ms. RM broke down the circuit behaviours before and after closing the switch. This approach helped highlight the change in current flow due to the switch closure:

> *Teacher: current will move from positive terminal, goes to x and to y, because the switch is in between. If the switch is still open, it goes to both x and y. it is only when it is open and they say now they are closing it, what is going to happen? if you look at the circuit before the switch was even closed, the current was flowing on both x and y, meaning a series circuit. are together?...... [Learners: yes]*
>
> *Teacher: now, when you are going to close the switch, the current will find the easier path, what is going to be the easy path? ……………………………. [Learners: the branch that has the switch.]*
>
> *Teacher: the line that has the switch, meaning that the circuit to allow the current through the switch branch. The initial current wasn't going through the branch because the switch was open. The easy path connects with the y branch, and closes the x branch. The x won't have a reading and y will have a …………[Learners: reading]*

Teacher: why does y become more brighter? it is because the voltage of the battery is going to be the voltage of y. but when the switch was open, it was splitting the voltage. So the answer is ……… [Learners: A]

The learners were able to identify the branch that held the switch as the branch that had an easier path for current, thus, demonstrating active engagement in the discussion. The teacher then explicitly linked voltage distribution to the bulb brightness and this helped to solidify the concept of potential difference in circuits. Learner 1's statement that "all the bulbs will be off because we use the switch to switch them on or off" showed a misunderstanding of series versus parallel circuits, as the learner seemed to have assumed that the switch acted as a global power switch rather than changing the circuit configuration. Ms. RM was able to address this misconception by explaining that the switch affected the current path and not the whole circuit. Hence, ensuring that the learners understood the localised effect of the switch in this circuit.

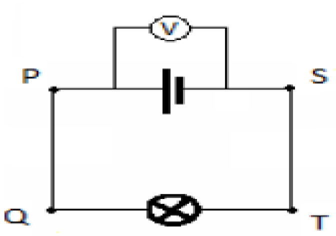
When Learner 2 incorrectly chose letter D, which implied that current continues to flow through both X and Y, this showed that the learner failed to recognise that closing the switch created a short circuit that redirected all the current through bulb Y and bypassed bulb X. Ms. RM's explicit statement that "the easy path connects the Y branch and closes the X branch. The X won't have a reading" connected the misunderstanding, showing that bulb X effectively became an open circuit once the switch was closed.

5.7 Teachers' strategies for addressing misconceptions from Question 6

Question 6 sought to determine whether teachers were aware that learners often fail to distinguish between voltage and current. Specifically, this question aimed to explore the 'voltage and current not distinguish' misconception.

Question 6

A 6 V battery is connected to a bulb as shown above in the diagram. A voltmeter is the connected between P and S. Next it is connected between P and Q, then Q and T and finally T and S. what are the voltmeter readings between the various points?



	PS	PQ	QT	TS
(E)	6	0	6	0
(F)	6	6	6	6
(G)	6	2	2	2
(H)	6	3	0	3

The correct answer is (A)

Which wrong option do you expect your learners to choose?

Mr. MT	Mr. NM	Ms. RM
B	B	B

All three teachers anticipated their learners to choose option B, and offered similar insights into why they thought their learners might have chosen option B. They indicated that learners often thought that voltage remains the same throughout the entire circuit.

5.7.1 Mr. MT's strategies for addressing misconceptions in question 6

Mr. MT's approach to addressing misconceptions, as explored in question 6, can be characterised as authoritative and non-interactive. This was seen when he started by prompting his learners to state what the correct answer was, to which they responded "A." He then went on to explain to them why option A is correct, and he did not use any strategy to explore the misconception that he anticipated his learners to hold, neither did he attempt to uncover any other misconceptions.

> Teacher: the correct answer is option….. [Learner: A]
>
> Teacher: A. reads out the statement for question 6. We said the correct answer is option A. if we can check, between P and S we have a voltmeter, between Q and T we have a bulb that is why we are saying at PS is going to be 6 and at QT is going to be 6. Why are saying at PQ and ST is zero? Because between PQ and ST we don't have either the resistor or the voltmeter. That is why we are saying it is zero.

Mr. MT explained to learners why the voltmeter readings at PS and QT were 6V and why PQ and ST had a reading of zero by explaining where voltage can be measured in a circuit. He further reinforced the relationship between voltage and circuit components by mentioning where voltmeters and resistors are located. This communicated to the learners that voltage is measured across the components that resist current flow, such as light bulbs or resistors, but not across plain conducting wires. But the teacher did not explore any common misconceptions such as the common belief held by many learners that voltage should always exist at every point in a circuit, without realising that it is only measured across components that resist current or the misconception wherein learners could be the thinking that voltage 'travels' like current instead of understanding that it is a measure of potential difference.

5.7.2 Mr. NM's strategies for addressing misconceptions in question 6

Mr. NM's approach supported active learning and helped learners to critically analyse their misconceptions rather than passively accept information. The approach can be classified as dialogic and interactive, as the teacher initiated the interaction by reading out the question to the learners verbatim and then proceeded to draw the circuit diagram on the board. This provided the learners with a visual reference to follow during the discussion, and during the discussion, instead of confirming the learners' answers, Mr. NM asked them to explain their reasoning before he would confirm the correct answer. When one learner indicated that she chose A, and the reason for that was because in the previous question (question 4), the teacher said, "if a single bulb is connected in series, it will read all the voltage”. Mr. NM did not immediately confirm the answer, but instead, he led learners through their reasoning process by prompting them with further questions and encouraging peer responses. This seemed to have allowed learners to effectively engage with the concept instead of passively receiving the information and it also enabled the learners’ misconceptions to surface so that they may be addressed

> *Teacher: what do others say? ……….[Learner 2: it is letter B.]*
>
> *Teacher: the correct answer there is letter A. Because PS has 6 V battery and the very same 6 V is going to be experienced by this bulb. Are we together? ………. [Learners: yes]*
>
> *Learner 3: the reason is that resistors in series are potential difference dividers, if we had two bulbs there, they were going to divide the voltage.*
>
> *Learner 4: so the what about those zeros?*
>
> *Learner 3: because we do not have resistors between those points, you cannot have potential difference if we do not have resistors.*
>
> *Teacher: correct.*

Mr. NM asked for other options from learners and when Learner 2 chose option B, which was the misconception that he anticipated his learners to have, he did not take the opportunity to address that misconception, instead he quickly confirmed option A as being the correct answer. The teacher missed an opportunity to encourage deeper engagement with the learner’s incorrect reasoning before moving forward. A question on why the learner thought the answer was option B and what made them think that way would have assisted in addressing the misunderstanding.

5.7.3 Ms. RM’s strategies for addressing misconceptions in question 6

Ms. RM guided learners toward the correct answer through directed questioning without exploring alternative options in depth. Even though she allowed her learners to articulate their reasoning, the discussion was structured in a way that led them to a predetermined conclusion. Hence, the approach was classified as authoritative, but she also engaged her learners by asking them to justify their responses, making the approach interactive. One learner reasoned that the teacher told them that “the voltmeter only reads where there are resistors, not where there are conductors only.”, which was the reason she chose option A. The discussion in this section led learners to link the concept being explored to their prior knowledge. This was seen when Learner 1 recalled Ms. RM’s previous lesson.

While the responses that were discussed during the interaction made no explicit mention of the misconception that voltage is present everywhere in a circuit. Ms. RM clarified it when she stated that:

> *Teacher: we only read the voltmeters on resistors not on the conducting wires. We don't get any readings when we connect the voltmeters on the wire that does not have a resistor. That is why on PQ the reading is zero and between PS there is a battery, therefore there is a battery and also between QT there is a reading between of the bulb. Makes sense?.............[Learners: yes]*
>
> *Teacher: the reading is only on PS and also QT but PQ and ST they do not have any voltmeter reading, because those connecting wires are not connected to any resistor……….[Learners: yes]*

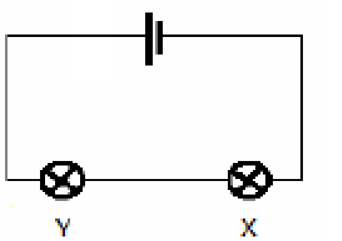
This addressed the thinking of learners who often think that voltage exists everywhere. So, her explanation helped them understand that voltage only exists across components that resist the flow of current. Even though she was able to lead her learners to the correct understanding of this question, she only focused on why option A was correct and did not analyse why learners might have chosen options B, the anticipated option, to D. This made her miss the opportunity to allow her learners to self-correct their misconceptions instead of just accepting her explanations. Instead of confirming PQ and ST had zero readings, she could have asked questions on why others could have thought that there might be voltage between those points, and what placing a resistor there would do.

5.8 Teachers' strategies for addressing misconceptions from Question 7

This question explored the sequential model misconception which aimed to determine whether teachers were aware that learners often believe that a change in the circuit will affect current in parts of the circuit located 'ahead' of the change, but not in parts located 'behind' it.

Question 7

What happens to the brightness of the bulbs X and Y if we add a resistor between them?



(E) X and Y both less bright
(F) X unchanged, Y less bright
(G) X less bright, Y unchanged
(H) X and Y both unchanged

The correct answer is (A)

Which wrong option do you expect your learners to choose?

Mr. MT	Mr. NM	Ms. RM
C	C	D

Both Mr. MT and Mr. NM anticipated their learners to choose option C and indicated that the learners were likely to assume that the resistor added in between X and Y would reduce the current passing through bulb X, but bulb Y would not be affected due to its position in the circuit. Whereas, Ms. RM selected option D, citing the reason that "the learners were likely to believe that in a series circuit, current is the same everywhere, and if current is constant, then the brightness would also be the same."

5.8.1 Mr. MT's strategies for addressing misconceptions in question 7

Even though Mr. MT predicted that his learners would choose option C, his approach of telling them that the correct answer for all questions was option A prevented his classroom from exploring any other options except for option A and thus, learners who chose other options and not option A had their misconceptions not challenged. This approach was characterised as authoritative and non-interactive. He started by prompting his learners to state what the correct answer was, and all of them sang "A". Instead of asking them to articulate their reason for that choice, he proceeded to explain why option A was the correct option.

> *Teacher: option A. x and y both less bright. Why do we say they are both less bright? If we connect more resistors in series, then if we want the current, obviously we are going to have more resistance, if we use the formula I=V/R, we are going to be dividing with a bigger number, then both x and y they are going to be less bright.*

Rather than directing his learners straight to the correct answer, the teacher could have encouraged them to compare scenarios through explorative questions seeking to uncover whether the learners thought that adding a resistor always made both bulbs dimmer and what they thought would happen had the resistor been placed in parallel instead of in series. Also, instead of simply stating that both X and Y would be less bright, he could have asked his learners what would happen if another resistor was added and whether that would decrease the brightness of the bulbs even more. This would have helped the learners visualise how current behaves in series circuits. Some learners might have thought that only one light bulb would dim, rather than both of the bulbs, and as Mr. MT did not ask the learners why they thought option A was correct, nor did he engage those learners who may have chosen B, C or D, the misconceptions they may hold may have been left hidden and unchallenged.

5.8.2 Mr. NM's strategies for addressing misconceptions in question 7

Mr. NM started by asking his learners to identify the correct answer. When the learners identified the correct answer as option A, rather than just confirming that option A was the correct answer, he asked his learners to explain their choice. This pushed the learners to think critically as opposed to just memorising the answer, and thus, the approach can be characterised as interactive. While he encouraged reasoning, the discussion was still teacher-directed, guiding learners toward the correct answer without fully exploring alternative options, and this made the approach authoritative as well. To explain, he linked the brightness of the light bulbs to the division of voltage in series across resistors, as voiced by Learner 1:

> *Learner 1: resistors in series are potential difference dividers.*
>
> *Teachers: is wrong?...........[Learners: it is correct.]*
>
> *Teacher: what happens to the brightness of x and y if add a resistor between them? x and y both will be less bright, meaning they will be sharing that potential difference, meaning they become less bright.*

This helped the learners to understand the underlying principle instead of just knowing the answer and reinforced the role of Ohm's law in determining the brightness of the light bulb. Even though Mr. NM directed the learners towards the correct answer, he did not engage with learners who may have chosen other options instead of option A. And, by so doing the teacher missed the chance to uncover misconceptions and having a deeper discussion of the concept. Also, while he mentioned that the bulbs "share potential difference," he did not fully explain to the learners as to why the addition of more resistors decreased the brightness.

5.8.3 Ms. RM's strategies for addressing misconceptions in question 7

Ms. RM's approach was authoritative in that she guided her learners toward the correct answer using directed questioning rather than open-ended exploration. She structured the discussion such that it confirmed why option A was correct instead of deeply exploring alternative options. She promoted active participation as well by engaging her learners by asking them to justify their reasoning and linking their answers to their prior knowledge and, this made her approach interactive as well.

> *Teacher: why A?...Okay what happens when we add a resistor in a series circuit? are we increasing or decreasing the resistance? ……….. [Learners: increasing]*
>
> *Teacher: if we are increasing the resistance, we need to know that resistance is inversely proportional to the current. If we are going to have more resistance, we will have less current. As long as they are connect in series.*

This encouraged critical thinking among the learners rather than passive answer confirmation as the teacher was able to check the learners' conceptual understanding before proceeding with the discussion. To link the learners' answer to Ohm's law, Ms. RM explicitly introduced the inverse relationship between resistance and current. This helped learners connect the concept to fundamental electricity principles and reinforced how the addition of resistors in series circuit connections affects the whole circuit.

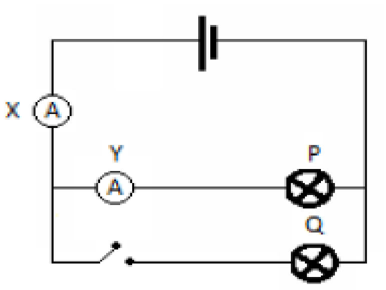
Ms. RM's strategy, while it explained why option A was correct, it did not address why other options were incorrect and therefore, she missed the chance to challenge misconceptions that could be held by learners who chose other options, including option D that she predicted but did not explore when giving feedback. She could have uncovered hidden misconceptions and helped learners self-correct by asking directed questions on whether any of the learners thought different options were correct and why, and also what the learners thought would happen had they added a resistor in parallel instead of in series.

5.9 Teachers' strategies for addressing misconceptions from Question 8

Question 8 explored teachers' understanding of misconceptions related to power supply and parallel circuits.

Question 8

How do the readings on the ammeters X and Y change if the switch is closed?



(E) X increases, Y unchanged
(F) X unchanged, Y decreases
(G) X decreases, Y decreases
(H) X increases, Y decreases

The correct answer is (A)

Which wrong option do you expect your learners to choose?		
Mr. MT	Mr. NM	Ms. RM
C	D	D

Mr. MT chose option C and reasoned that he thought that the light learners were likely to think that current decreases in one section of a parallel circuit because of current division. On the other hand, both Mr. NM and Ms. RM chose option D, which suggest that they may not have been aware of the common misconception that learners often hold associated with current division in parallel circuits.

5.9.1 Mr. MT's strategies for addressing misconceptions in question 8

Mr. MT's approach was authoritative and non-interactive. He explicitly told his learners that the correct answer was option A, and this reinforced a teacher-centred approach where the teacher controlled the flow of information instead of facilitating a discussion. He also did not engage his learners in articulating their reasoning or exploring alternative answers. The learners who chose different options other than option A were not allowed to explain their thought processes, leaving their misconceptions unaddressed

> *Teacher: how do the reading on ammeter x and y changes if the switch is closed? Then the correct option is letter……………….[Learners: A.]*
>
> *Teacher: letter A. it says x increases and y remain unchanged. if you can check when the current starts to move more current will be on x as for why does y remain unchanged I also do not know.*

Instead of asking learners to explain their answer choices, Mr. MT told them the correct answer directly. This led to learners not critically evaluating why the answer is correct and those who may have chosen a different option, possibly held misconceptions, were not engaged or corrected, thus missing an opportunity to challenge misconceptions about how current flows when a resistor is added in parallel. Questions such as asking if anyone chose B, C, or D and why, and as well as why Y remain unchanged while the brightness of X increased, would have been helpful in uncovering misconceptions that his learners held.

Mr. MT openly admitted to not knowing why bulb Y remained unchanged, even though he told them what the correct answer was. This was found to be problematic because teachers play a critical role in clarifying concepts and his admission, without a promise of further referral, left the learners without a full understanding of the concept and this had the potential to further confusion or further reinforcement of the misconceptions.

5.9.2 Mr. NM's strategies for addressing misconceptions in question 8

The approach by Mr. NM was classified as dialogic and interactive as he began this question by prompting his learners to voice out their answers and articulate their reasons for their answer choices. When the learners indicated that the correct answer was option A, instead of confirming the correct answer immediately, Mr. NM explored other options by opening the discussion so that other learners could mention their alternative choices with reasons, and this allowed learners to debate and challenge each other's reasoning. This encouraged the learners' critical thinking and helped them to self-correct their own misconceptions by engaging multiple learners' perspectives. The learners through their discussion, introduced the concept of current division:

> *Teacher: when the swich is open, meaning they will experience a short circuit, meaning that there will be no flow of current in Q.*
>
> *Learner 1: yes, and when we close the switch, we have a resistance of Q that has its current . and current of Q and current of A, gives us the total sum of ammeter x.*
>
> *Teacher: do you hear what he is saying?....[Learners: it is correct]………. [Learner 2: I said the answer C]*
>
> *Teacher: you said it is C, resistors in what? Are what?.........[Learner 2: in parallel. are current dividers]*
>
> *Teacher: and C is saying x will decrease and y will also decrease………[Learner 2: yes]*
>
> *Teacher: I have to go with 'learner 1' s answer, he said his answer is A. So at first the switch was open, so at first the switch was open, and the only current which was flowing that is coming from x is very same current that is flowing at y and is flowing through bulb p. now we close the switch. Since we close the switch , we introduce another bulb q, and it comes with its own current. So the current at x has to increase because it is not the same current that was flowing at y.*

This showed that learners were able to apply their knowledge of current division in parallel and series circuits to this question. This kind of approach promoted learner-led explanations and reinforces conceptual understanding. When learner 2 indicated that he chose a wrong answer, option C, Mr. NM asked probing questions to guide the learner's reasoning, thus encouraged active thinking and helped the learner verbalise his reasoning, making misconceptions easier to diagnose. The teacher further checked if the learner understood that parallel resistors act as current dividers, and he acknowledged learners' reasoning before confirming the correct answer.

By following this approach, Mr. NM was able to create an environment where learners' mistakes were corrected constructively. This he did by walking the learners through what happened before and after closing the switch. Although this approach helped learners comprehend concept explored by the question, the teacher did not fully explain why current through Y remains unchanged. He could have asked directed questions like what happens to the voltage across Y when the switch is closed or whether the resistance in Y's branch change or not.

5.9.3 Ms. RM's strategies for addressing misconceptions in question 8

Ms. RM's approach was classified as authoritative and non-interactive because, unlike in all the other questions, where Ms. RM used directed questions to systematically uncover learners' misconceptions before confirming the correct answer, in this case she started by using a verbal explanation to tell the learners what the answer is without engaging them or checking what misconceptions they held:

> *Teacher: (draws the circuit on the board and reads the question)… let us start before we close the switch, before we close it, there was only one path but after we closed it, there are two paths. Provided the voltage remains the same. Before we closed the switch the current at y was the same as at X. when we close the switch, x reads the total current.the question asked what will happen, what did you choose? Because y has not changed, current in y remains the same but in x increases. Understood?*
>
> *Learners: yes*

This approach assumed that the learners already understood why the answer was correct and this missed an opportunity to uncover learners misconceptions, particularly regarding how the current changes in a parallel circuit when a switch is closed. Instead of a guided inquiry, Ms. RM used immediate verbal explanation. Though the oral explanation was correct, it did not provoke the learners to think diagnostically about the concept, nor urged their active reasoning or involvement, nor did it tackle any misconceptions they may have had.

5.10 SUMMARY

This chapter explored the teachers' enacted strategies used during the feedback sessions to address the misconceptions, based on classroom observations. The Teacher Talk framework was used to analyse the enacted strategies, and in the majority of instances observed, teachers relied on authoritative feedback rather than dialogic engagement. There was often a disconnect between the teachers' planned strategies to address misconceptions in Chapter 4 and the actual teaching strategies enacted during feedback sessions observed. The chapter emphasised the need for professional development focused on enhancing the teachers' ability to engage learners in meaningful discussions and effectively address misconceptions.

6. CHAPTER SIX: DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

In Chapters four and five, the data collected throughout this study was presented and discussed to answer the sub-questions that guided this study. In this chapter, the key findings of the study are synthesised, an analysis of the three teachers as case studies is presented, and the effectiveness of their strategies is discussed. The chapter also explores the implications for various stakeholders, provides recommendations for improving science teaching, and finally, it identifies and proposes directions for future research. The findings are discussed case by case for a thorough description of the teachers' awareness of learners' misconceptions and their planned and enacted strategies for addressing the misconceptions.

6.2 SUMMARIES OF THE FINDINGS

In this study, the teachers were given a conceptual understanding multiple choice test with options to choose the correct answer from. The option corresponding with the correct answer was specified. The teachers were asked to select, for every question, the option that they believed their learners would select. The questions aimed to check for their awareness of the particular misconceptions documented in the literature. They then had to provide reasons for choosing the particular option as the choice their learners would make, and they were also asked to indicate the strategy they planned to use to address their learners' misunderstanding. The test was then administered to the learners and then marked by the participating teachers. The teachers then gave feedback to their learners during normal teaching hours. The feedback sessions were video recorded and transcribed for analysing the teachers' enacted strategies for addressing the misconceptions. Because the study focused on teachers only, the learners' responses and performances are excluded in this dissertation. The teachers' planned strategies were studied through the lens of PCK whereas their enactment during feedback sessions was studied through the lens of teacher talk. For each teacher, two misconceptions are used as illustrative examples of how their awareness related to their planned strategies and, ultimately enactment during feedback sessions.

6.2.1 Case of Mr. MT

Table 6.2.1 below summarises Mr. MT's awareness of the misconceptions, his planned strategies to address them and his enacted strategies during feedback.

Table 4.1: Summary of Mr. Mt's awareness, planned and enacted strategies

Misconception Model (Question)	**Awareness**	**Planned strategies**	**Enacted strategies**
Attenuation (The belief that current or charge instead of energy is converted to light)	No awareness. The chosen option and reason are unrelated to the documented misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Authoritative, non-interactive. Provided correct answer without conceptual questioning.
Weakening current (The belief that current gets "used up" and therefore weakens in a circuit)	Showed awareness. The chosen incorrect option is related to the misconception, while the reason is partially related to the misconception.	The strategy only referred to curricular saliency as the teacher proposed providing standardised facts, i.e.: stated that current remains the same in a series circuit. No mention of representations and conceptual teaching strategies.	Authoritative, non-interactive. Gave correct answer without probing learners' reasoning.
Clashing currents (The belief that current flows from both terminals of the battery in opposite directions," clashing" at the resistor to produce energy)	No awareness. Did not anticipate misconception	There was no plan for this misconception, but the plan was to explain the correct answer.	Not addressed in feedback. However, the correct answer was provided using an authoritative, non-interactive explanation.
Empirical rule (The belief that a light bulb farther from the battery will glow dimmer)	shows awareness; however he misinterpreted it as current depletion, a reason not related to brightness reasoning.	The strategy only referred to curricular saliency as the teacher proposed providing standardised facts, i.e.: mentioned Ohm's law. No mention of representations and conceptual teaching strategies.	Authoritative, non-interactive. Gave formula-based explanation without engaging learners.
Short circuit (The belief that wires in a circuit without electrical devices can be ignored when analysing the circuit)	Shows awareness. the chosen option was related to misconception, although he did not fully explain current paths; the reason was not related to misconception.	The strategy only referred to curricular saliency as the teacher proposed providing standardised facts, i.e.: mentioned short circuit conditions. No mention of representations and	Authoritative, non-interactive. Defined short circuit but did not verify learner understanding.

		conceptual teaching strategies.	
Voltage vs. current (The belief that current and voltage are the same or voltage is a form of "used-up current)	shows awareness. The chosen option was related to misconception, although the reason was not related to the misconception.	The strategy only referred to curricular saliency as the teacher proposed providing standardised facts, i.e.: addressed voltage and current separately. No mention of representations and conceptual teaching strategies.	Authoritative, non-interactive. Explained concepts but did not check for understanding.
Sequential (The belief that a change in the circuit will affect current in parts of the circuit located "ahead" of the change, but not in parts located "behind" it)	No awareness. Did not anticipate misconception	There was no plan for this misconception, but the plan was to explain the correct answer.	Not addressed in feedback. However, the correct answer was provided using an authoritative, non-interactive explanation.
Parallel circuit (The belief that if the number of resistors in parallel are increased, the total resistance will also increase)	No awareness. Did not anticipate misconception	There was no plan for this misconception; but the plan only mentioned formula use and procedural explanation.	Authoritative, non-interactive. Stated correct calculations but did not explore learners' reasoning.

As indicated in Table 6.2.1, Mr. MT showed more awareness of some misconceptions while also failing to recognise others. One of the misconceptions that he recognised was the weakening current model when he chose the option showing that his learners might incorrectly think that the current is "used up". The reason for this choice was also related to this misconception. However, his planned strategy only focused on factual explanations and did not use representations or engaging questioning techniques. He proposed reminding learners of standardised facts about current, i.e., staying constant in series connections and only diving in parallel setups as a way of getting learners to understand the correct answer. He enacted an authoritative and non-interactive strategy wherein he told learners the correct answer without probing his learners' reasoning, as predicted by his planned strategy. Contrastingly, Mr. MT did not show awareness of the clashing current misconceptions in which learners tend to think that electric currents flow both of the battery's terminals and meet at the bulb.

Instead, he predicted they would choose an unrelated option. As such, his planned strategy was also unrelated to the misconception but rather focused on providing standardised facts, i.e., the fact that conventional current flows from the positive to the negative terminal. The strategy was enacted as planned, focusing on authoritative discussions with minimal involvement of learners.

6.2.2 Case of Mr. NM

Table 6.2.2 below summarises Mr. NM's awareness of the misconceptions, his planned strategies to address them and his enacted strategies during feedback.

Table 6.2.2: Summary of Mr. NM's awareness, planned and enacted strategies

Misconception model	Awareness	Planned strategies	Enacted strategies
Attenuation (The belief that current or charge instead of energy is converted to light)	Shows awareness. The chosen option and reason are related to the misconception.	Curricular saliency: differentiated between current and energy. No mention of representations and conceptual teaching strategies.	Dialogic, interactive. Guided learners through reasoning.
Weakening current (The belief that current gets "used up" and therefore weakens in a circuit)	Shows awareness. The chosen option and reason are related to the misconception.	curricular saliency: addressed current continuity. No mention of representations and conceptual teaching strategies.	Dialogic, interactive. Encouraged learner responses but provided explanations too soon.
Clashing currents (The belief that current flows from both terminals of the battery in opposite directions," clashing" at the resistor to produce energy)	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Not addressed in feedback. However, the correct answer was provided using a dialogic, interactive discussion.
Empirical rule (The belief that a light bulb farther from the battery will glow dimmer)	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Dialogic, not fully interactive. Did not let learners reason through it.
Short circuit (The belief that wires in a circuit without electrical devices can be ignored when analysing the circuit)	Shows awareness. The chosen option and reason are related to the misconception.	Curricular saliency: discussed how short circuits affect circuit function. No mention of representations and conceptual teaching strategies.	Dialogic, interactive. Used prediction-based questioning but lacked structured representation.
Voltage vs. current (The belief that current and voltage are the same or	Shows awareness. The chosen option and reason are related to the misconception.	Curricular saliency: addressed voltage as potential difference.	Dialogic, interactive. Engaged learners through questioning but provided explanations too soon.

voltage is a form of "used-up current)		No mention of representations and conceptual teaching strategies.	
Sequential (The belief that a change in the circuit will affect current in parts of the circuit located "ahead" of the change, but not in parts located "behind" it)	Shows awareness. The chosen option and reason are related to the misconception.	Curricular saliency: mentioned current flow effects. No mention of representations and conceptual teaching strategies.	Dialogic, semi-interactive. Used questioning but did not fully explore misconception.
Parallel circuit (The belief that if the number of resistors in parallel are increased, the total resistance will also increase)	Shows awareness. The chosen option and reason are related to the misconception.	Curricular saliency: addressed resistance calculation. No mention of representations and conceptual teaching strategies.	Dialogic, interactive. Facilitated reasoning but did not explicitly challenge misconception.

Table 6.2.2 indicates that Mr. NM showed a strong awareness of numerous misconceptions, with a few others overlooked or misinterpreted. For instance, he recognised the attenuation model misconception, wherein learners normally confuse current with energy flow. He planned to use a strategy that distinguishes current and energy, using questioning techniques as a conceptual strategy. In actual teaching during feedback, he adopted a dialogic and interactive strategy that saw him successfully guide his learners through reasoning instead of providing direct and immediate explanations. Similarly, he also showed an awareness of the short circuit misconception, in which learners tend to experience difficulty understanding how current bypasses circuit components. To address this, he planned to use verbal questioning, and the enacted strategy that he used was interactive and dialogic, using prediction-based questioning.

However, Mr. NM did not show awareness of the empirical rule model of misconception, depicted by learners thinking that bulbs farther from the battery would be dimmer due to distance effects. Because he did not anticipate this misconception but instead viewed it as a voltage-sharing issue, he planned a strategy that focused on voltage division instead of brightness reasoning. Due to this, he employed an explanation-heavy and semi-interactive strategy that did not allow the learners to reason through their misconception. Even though Mr. NM demonstrated a greater awareness and ability to uncover and address misconceptions, his tendency to rush to explain the concepts limited a deeper conceptual engagement with his learners' thinking.

6.2.3 Case of Ms. RM

Table 6.2.3 below summarises Ms. RM's awareness of the misconceptions, his planned strategies to address them and his enacted strategies during feedback.

Table 6.2.3: Summary of Ms. RM's awareness, planned and enacted strategies

Misconception model	Awareness	Planned Strategies	Enacted strategies
Attenuation (The belief that current or charge instead of energy is converted to light)	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Dialogic and moderately interactive. Engaged learners but did not fully challenge misconceptions.
Weakening current (The belief that current gets "used up" and therefore weakens in a circuit)	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Dialogic, semi-interactive. Used class discussion but lacked deep probing.
Clashing currents (The belief that current flows from both terminals of the battery in opposite directions," clashing" at the resistor to produce energy)	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Not addressed in feedback. However, the correct answer was provided using a dialogic, interactive discussion.
Empirical rule (The belief that a light bulb farther from the battery will glow dimmer)	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Not addressed in feedback. However, the correct answer was provided using a dialogic, interactive discussion.
Short circuit (The belief that wires in a circuit without electrical devices can be ignored when analysing the circuit)	Shows awareness. The chosen option and reason are related to the misconception.	Curricular saliency: explained why circuits fail in short circuits. No mention of representations and conceptual teaching strategies.	Dialogic, semi-interactive. Encouraged learner discussion but lacked structured engagement.
Voltage vs. current (The belief that current and voltage are the same or voltage is a form of "used-up current)	Shows awareness. The chosen option and reason are related to the misconception.	Curricular saliency: mentioned voltage and current separately. No mention of representations and conceptual teaching strategies.	Dialogic, semi-interactive. Did not probe learners' reasoning deeply.
Sequential (The belief that a change in the circuit will affect current in parts of the circuit located "ahead" of the change, but	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Not addressed in feedback. However, the correct answer was provided using a dialogic, interactive discussion.

not in parts located “behind” it)			
Parallel circuit (The belief that if the number of resistors in parallel are increased, the total resistance will also increase)	No awareness. The chosen option and reason are unrelated to the misconception.	There was no plan for this misconception, but the plan was to explain the correct answer.	Dialogic, semi-interactive. Engaged learners but lacked structured questioning.

Table 6.2.3 demonstrates that Ms. RM was able to recognise some misconceptions but showed no awareness of others. For example, she showed more awareness of the short circuit misconception, wherein learners tend to misunderstand how current can bypass certain circuit components when a short circuit takes place. She planned to discuss the reasons why electric circuits fail in short circuits. As a conceptual strategy, she employed the use of prediction-based discussions, which would allow her learners to articulate their expectations before she gave them explanations. However, her enacted strategy during her feedback session was dialogic and not fully interactive, as she engaged her learners but had limited conceptual depth due to the lack of structured questioning. She also showed an awareness of the voltage versus current confusion misconception, characterised by learners struggling to differentiate between these two quantities. In her planned strategy to address this misconception, she mentioned current and voltage separately. In practice, she used a dialogic but semi-interactive approach to engage her learners but did not probe their reasoning deeply during feedback.

She, however, did not show awareness of the sequential model misconception, where learners tend to think that only components that come after the change to a circuit are affected by the circuit changes. Since she did not anticipate this misconception, she did not include it in her planned strategies, thus, it was not corrected in her feedback, instead, she focused on explaining the correct answer and this left learners who held this misconception not challenged to rethink their understanding of the concept. Even though Ms. RM encouraged learner participation by using discussion-based strategies, due to the lack of structured representations and questioning, her strategies presented limited effectiveness in challenging misconceptions.

6.3 DISCUSSION OF THE FINDINGS

Teachers in this study demonstrated awareness of common misconceptions in electric circuits, such as the weakening current model and voltage vs. current misconceptions, but they often failed to recognise other misconceptions, such as the clashing current model. These findings align with Moodley and Gaigher (2019), whose study found that teachers often recognise some common misconceptions but overlook others, especially those related to energy transfer and current flow. Similarly, Van der Merwe and Gaigher (2011) reported that incomplete teacher awareness can perpetuate misconceptions across grade levels. Also recent studies Şen et al. (2022) and Nkuna (2023) confirm that diagnostic skills are linked to teachers' ability to implement conceptual teaching strategies, whereas lack of awareness leads to procedural teaching that does not address misconceptions.

Teachers' planned strategies focused mainly on the curricular saliency, thus providing correct answers and factual explanations, while limitedly incorporating conceptual teaching strategies or representations. Studies by Gaigher (2014) and Moodley and Gaigher (2019) revealed that teachers often sequence concepts logically but neglect conceptual engagement and the use of multiple representations. Similarly, Mazibe et al. (2020) noted that teachers with good content knowledge and awareness of some misconceptions still have a challenge of translating this awareness into rich, conceptual teaching. The importance of integrating analogies, diagrams, and hands-on models is highlighted by Van der Merwe & Gaigher (2011) and Tippett (2016), because these help learners to rebuild their understanding, but such strategies were largely absent in this study.

Most teachers enacted authoritative, non-interactive feedback, by confirming the correct answers without probing learners' reasoning. Only occasionally, did the teachers use dialogic and interactive approaches. Scott et al. (1998) and Mortimer& Scott (2003) identified two key patterns: (i) authoritative talk (teacher-led, explanation-based) and dialogic talk (learner-centred, reasoning-based). The dominance of authoritative talk in this study matches their observation. Additionally, Faikhamta& Lertdechapat (2021) highlighted that non-interactive talk limits opportunities for conceptual change, reinforcing misconceptions instead of correcting them. Also, recent studies by researchers like Şen et al.(2022), Nkuna (2023) and OGUNDARE et al. (2024) posit that interactive strategies, such as Socratic questioning and prediction-based discussions, are more effective for conceptual development.

There was also a notable disconnect in the sense that even when teachers showed awareness of misconceptions and planned to address them, their enacted teaching strategies did not promote conceptual change, often reverting to procedural explanations. Mazibe et al. (2020) and Moodley & Gaigher (2019) reported the same misalignments, where the teachers' theoretical knowledge of the misconceptions did not translate into effective classroom practice. Studies by Chen et al. (2013) and Nasri (2020) demonstrated that learners exposed to prediction-based activities and multiple representations develop stronger conceptual understanding than those who experience only procedural teaching.

This study, therefore, underscores the need for targeted professional development that enhances teachers' diagnostic skills, encourages the use of conceptual teaching strategies, and fosters dialogic classroom discourse. Fitz (2019) and Weitzel & Blank (2020) advocate for diagnostic assessment tools and structured questioning to uncover misconceptions before teaching. Teacher training programs should explicitly address misconceptions-focused instruction and provide opportunities for teachers to practice interactive, conceptual teaching strategies (Van der Merwe & Gaigher, 2011; Moodley & Gaigher, 2019).

6.4 CONCLUDING REMARKS

This study explored teachers' awareness of common misconceptions, how they planned to address the misconceptions they anticipated their learners would hold and the actual strategies they used during feedback in their classrooms. The findings of this study revealed variations in the teachers' awareness, wherein some of the misconceptions were correctly predicted, others were overlooked or misinterpreted. It was also demonstrated that while the teachers showed more awareness of some of the misconceptions, they planned strategies that only considered curricular saliency in PCK, i.e., centred around providing the correct answer. There were no indications of conceptual teaching strategies and representations. This study found that teachers who were aware of misconceptions planned factually correct explanations, but they did not always structure their lessons in a way that conceptually targets learner difficulties. The strategies that they planned showed a lack of representational tools like analogies, circuit diagrams, or practical experiments that would have assisted the learners to visualise and rebuild their understanding. On the other hand, the teachers who showed less awareness of the misconceptions demonstrated gaps in their PCK, and this led to planned strategies that did not anticipate or actively seek to address the misconceptions. This misalignment between teachers' awareness of misconceptions and their teaching approaches hindered the effectiveness of their planned strategies in the promotion of conceptual change. This may have been caused by the fact that the teachers were just asked how they would address the misconception without specific focus on PCK components such as representations and conceptual teaching strategies they would use. Hence, their responses were already focused on providing reasons for the correct and the incorrect options, thus revealing the component of curricular saliency only. Perhaps future studies can consider formulating questions that are PCK-specific for a richer understanding of how teachers plan to address documented misconceptions.

It was also found that the enacted strategies revealed the teachers' strong tendency to lean toward an authoritative, non-interactive teacher talk, wherein the teachers rush to confirm the correct answers to learners without encouraging reasoning-based discussions. In a few instances where the teachers employed the use of dialogic and interactive feedback, greater conceptual engagement was visible, which enabled learners to articulate their reasoning and challenge their cognitive conflicts. But such cases were not often, and misconceptions were frequently addressed procedurally, instead of conceptually and, in most cases, the teachers were mainly focused on explaining the correct answer, they showed limited focus on explaining options that are wrong to their learners.

This study, therefore, concludes that where there was a strong awareness of the misconceptions, the teachers' curricular saliency was evident; however, the enactment of the strategies often demonstrated a lack of dialogic engagement. Where teachers demonstrated weak awareness of the misconceptions, neither the planned nor enacted strategies could directly address the misconceptions. Thus, this disconnect suggests that even in instances where the teachers are aware of the misconceptions, their ability to translate this awareness into effective and learner-centred instruction remains a challenge.

6.5 IMPLICATIONS AND RECOMMENDATIONS

Teachers should move away from authoritative, non-interactive approaches and increase their use of dialogic and interactive teaching strategies to address misconceptions in electric circuits. Research consistently shows that dialogic, interactive teaching strategies, where the teachers probe their learners' reasoning, encourage discussion, and facilitate argumentation, thus leading to deeper conceptual understanding and more effective remediation of misconceptions (Scott et al., 2006; Mortimer & Scott, 2003). Dialogic strategies allow learners to articulate their ideas, confront contradictions, and reconstruct their knowledge, which is essential for conceptual change (Tippett, 2016; Şen et al., 2022). Also, teachers should regularly use diagnostic assessment tools and probing questions to identify and address learners' misconceptions before and during instruction. Diagnostic assessment, like the concept inventories, open-ended questions, and prediction tasks, enables teachers to uncover learners' misconceptions and plan their teaching strategies accordingly (Fitz, 2019; Weitzel & Blank, 2020). Studies show that when teachers actively probe learners' thinking, they are better able to target teaching and facilitate conceptual change (Moodley & Gaigher, 2019; Nkuna, 2023).

Teachers should make greater use of multiple representations, for example, diagrams, analogies, and models) to help their learners to visualise and understand abstract concepts in electric circuits. The use of multiple representations is widely recognised as an effective strategy for addressing misconceptions and supporting conceptual understanding (Van der Merwe & Gaigher, 2011; Tippett, 2016). Analogies and visual models can help bridge the gap between learners' daily experiences and scientific concepts (Gaigher, 2014). Additionally, professional development programs should focus on enhancing teachers' Pedagogical Content Knowledge (PCK), particularly their ability to diagnose misconceptions and use conceptual teaching strategies. Targeted professional development has been shown to improve teachers' awareness of misconceptions and their ability to implement effective teaching strategies (Moodley & Gaigher, 2019). Programmes that emphasise PCK and conceptual change theory, such as Knowledge in Pieces (diSessa, 1993), equip teachers to better facilitate learning in complex topics like electric circuits.

The use of scripted lessons can be considered as a support tool for teachers, but their effectiveness is debated in the literature. Some studies suggest that scripted lessons can help less experienced teachers implement research-based strategies and maintain lesson coherence (Hoadley, 2012). However, critics argue that scripted teaching may limit teacher autonomy, responsiveness, and the ability to adapt to learners' needs (Ogborn, 2002; Moodley & Gaigher, 2019). It is therefore vital to view scripted lessons as one possible resource, to be used flexibly and adapted to context. Also, contextual factors such as time, resources, and school culture must be considered in order to improve teaching practices. Research emphasises that teachers' ability to implement dialogic and interactive strategies is often shaped by contextual factors, including class size, curriculum demands, and resource availability (Van der Merwe & Gaigher, 2011). Any intervention or recommendation should be sensitive to these realities to ensure practical feasibility and sustainability.

6.6. LIMITATIONS OF THE STUDY

This study was qualitative, and as Rahman (2016) posits, qualitative studies often rely on small, purposive samples which can limit generalisability to broader populations. This study had three major limitations to consider. First, the sample size of the study was only three teachers, and this may have limited the generalisability of the study's findings. Even though the findings provided valuable insights into teachers' awareness of learners' misconceptions, a bigger sample size could have uncovered more nuanced patterns of teachers' awareness and subsequent intervention teaching strategies. Second, the study's reliance on teacher interviews and classroom observations may have limited the capture of the complexity of the teachers' instructional reasoning and also, their strategies were requested using open questions that did not explicitly focus on PCK components.

Future research could strengthen this by integrating learner interviews as well as pre- and post-assessments of learner understanding to investigate how specific strategies influence conceptual change. Third, the study did not consider external contextual factors like curriculum requirements, time constraints and limited school resources, and these are likely to have influenced teachers' ability to implement misconception-focused instruction. Future research should involve the investigation of how these factors influence instructional practices.

6.6 SUGGESTIONS FOR FURTHER RESEARCH

From the findings of this study, four major recommendations are made for future research. First, future studies should track learners' conceptual understanding over time, thus exploring the impact of misconception-focused instruction in the long term. This would give insights into whether misconception-focused teaching strategies lead to sustainable conceptual change. Second, there should be research that explores the role of technology-based learning such as virtual experiments, adaptive learning platforms, and interactive simulations, in diagnosing and addressing misconceptions in electric circuits. Third, learners, scholars, and stakeholders would benefit from future studies that seek to understand how teachers learn to uncover and address misconceptions, effectively exploring how teachers develop their PCK related to misconception instruction, especially pre-service teachers. Finally, a comparative study that explores the difference between teachers who receive training in misconception-focused instruction versus those who do not could give us vital insight into how effective directed professional development programs are.

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APPENDIX 1: CONCEPTUAL TEST FOR LEARNERS

CONCEPTUAL UNDERSTANDING TEST FOR LEARNERS

- You may not write your name anywhere on worksheet
- Every question starts by a typical test item for you given in a box
- Note that a space is provided at the bottom of each test item for you to write down your answer
- You are required to answer all the items in the boxes
- Below every box you are required to give a reason why you chose the answer that you wrote.

Question 1

Why does a bulb light up when connected in a circuit?

(A) Electrical energy is converted to light

(B) Electrical charge is converted to light

(C) Electrical current is converted to light

(D) All of the above

The correct answer is ________

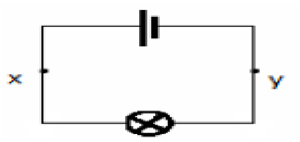
Write down the reason for your choice to question 1 above:

____

____

Question 2

How do the currents at point x and y compare?



(A) x = y

(B) x > y

(C) y > x

(D) x = 0

(E) y = 0

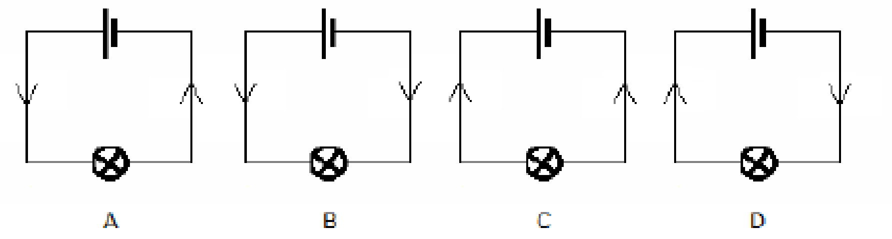
The correct answer is ________

Write down the reason for your choice to question 2 above:

____

Question 3

Which diagram correctly represents the flow of conventional current in the circuit?



The correct answer is ________

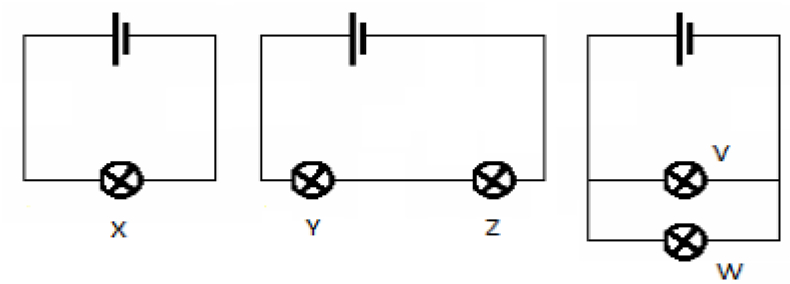
Write down the reason for your choice to question 3 above:

____

____

Question 4

Which bulb or bulbs are the least bright?



(A) y, z

(B) y, z, v, w

(C) w

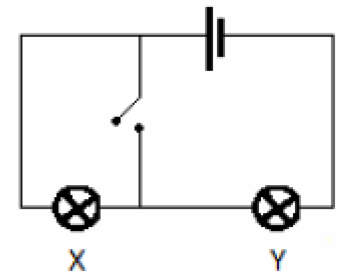
(D) x

(E) z and w

The correct answer is ________

Question 6

How does the brightness of the light bulbs change if the switch is closed?



(A) y brighter, x = 0

(B) both brighter

(C) y = 0 , x = 0

(D) x brighter, y = 0

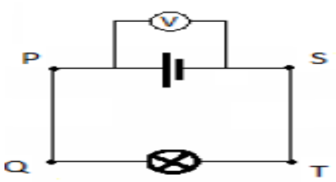
(E) no difference

The correct answer is ________

Write down the reason for your choice to question 6 above:

Question 5

A 6 V battery is connected to a bulb as shown above in the diagram. A voltmeter is the connected between P and S. Next it is connected between P and Q, then Q and T and finally T and S. what are the voltmeter readings between the various points?



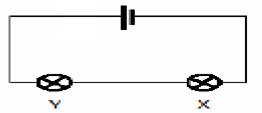
	PS	PQ	QT	TS
(A)	6	0	6	0
(B)	6	6	6	6
(C)	6	2	2	2
	6	3	0	3

The correct answer is ________

Write down the reason for your choice to question 5 above:

Question 6

What happens to the brightness of the bulbs X and Y if we add a resistor between them?



(A) X and Y both less bright

(B) X unchanged, Y less bright

(C) X less bright, Y unchanged

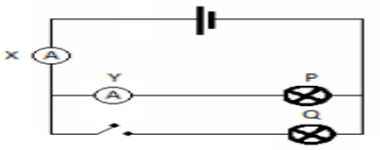
(D) X and Y both unchanged

The correct answer is ________

Write down the reason for your choice to question 9 above:

Question 7

How do the readings on the ammeters X and Y change if the switch is closed?



(A) X increases, Y unchanged

(B) X unchanged, Y decreases

(C) X decreases, Y decreases

(D) X increases, Y decreases

The correct answer is ________

Write down the reason for your choice to question 10 above:

QUESTIONNAIRE FOR TEACHERS

- Every question starts by a typical test item for learners given in a box
- You are not required to answer the items in the box
- You are required to answer the questions following the boxed items
- Note that the correct option of each item is given

- You are required to think about mistakes that your learners would make had they been given these test items

Question 1

Why does a bulb light up when connected in a circuit?

(E) Electrical energy is converted to light

(F) Electrical charge is converted to light

(G) Electrical current is converted to light

(H) All of the above

The correct answer is (A)

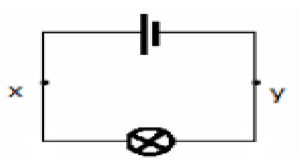
1.1 Which wrong option do you expect your learners to choose?

1.2 Why do you think they will choose this option?

1.3 How would you explain to your learners why the chosen option is incorrect?

Question 2

How do the currents at point x and y compare?



(F) x = y

(G) x > y

(H) y > x

(I) x = 0

(J) y = 0

The correct answer is (A)

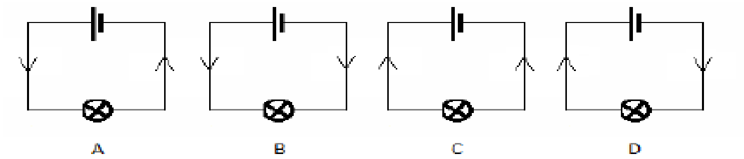
2.1 Which wrong option do you expect your learners to choose?

2.2 Why do you think they will choose this option?

2.3 How would you explain to your learners why the chosen option is incorrect?

Question 3

Which diagram correctly represents the flow of conventional current in the circuit?



The correct answer is (A)

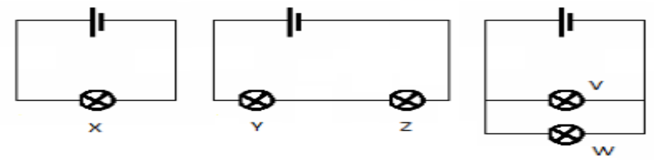
3.1 Which wrong option do you expect your learners to choose?

3.2 Why do you think they will choose this option?

3.3 How would you explain to your learners why the chosen option is incorrect?

Question 4

Which bulb or bulbs are the least bright?



(F) y, z

(G) y, z, v, w

(H) w

(I) x

(J) z and w

The correct answer is (A)

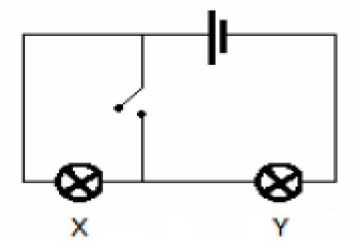
4.1 Which wrong option do you expect your learners to choose?

4.2 Why do you think they will choose this option?

4.3 How would you explain to your learners why the chosen option is incorrect?

Question 5

How does the brightness of the light bulbs change if the switch is closed?



(F) y brighter, x = 0

(G) both brighter

(H) y = 0 , x = 0

(I) x brighter, y = 0

(J) no difference

The correct answer is (A)

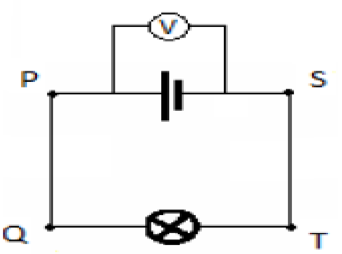
5.1 Which wrong option do you expect your learners to choose?

5.2 Why do you think they will choose this option?

5.3 How would you explain to your learners why the chosen option is incorrect?

Question 6

A 6 V battery is connected to a bulb as shown above in the diagram. A voltmeter is the connected between P and S. Next it is connected between P and Q, then Q and T and finally T and S. what are the voltmeter readings between the various points?



	PS	PQ	QT	TS
(D)	6	0	6	0
(E)	6	6	6	6
(F)	6	2	2	2
(G)	6	3	0	3

The correct answer is (A)

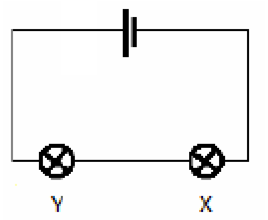
6.1 Which wrong option do you expect your learners to choose?

6.2 Why do you think they will choose this option?

6.3 How would you explain to your learners why the chosen option is incorrect?

Question 7

What happens to the brightness of the bulbs X and Y if we add a resistor between them?



(E) X and Y both less bright

(F) X unchanged, Y less bright

(G) X less bright, Y unchanged

(H) X and Y both unchanged

The correct answer is (A)

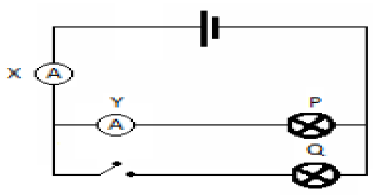
7.1 Which wrong option do you expect your learners to choose?

7.2 Why do you think they will choose this option?

7.3 How would you explain to your learners why the chosen option is incorrect?

Question 8

How do the readings on the ammeters X and Y change if the switch is closed?



(E) X increases, Y unchanged

(F) X unchanged, Y decreases

(G) X decreases, Y decreases

(H) X increases, Y decreases

The correct answer is (A)

8.1 Which wrong option do you expect your learners to choose?

8.2 Why do you think they will choose this option?

8.3 How would you explain to your learners why the chosen option is incorrect?

APPENDIX 2: INTERVIEW QUESTIONS

INTERVIEW QUESTIONS WITH REFERENCE TO THE CONCEPTUAL UNDERSTANDING TEST

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1. Question 1 of the test: the correct answer is (A)
   1.1. Which wrong option do you expect your learners to choose?
   1.2. Why do you think they will choose this option?
   1.3. How would you explain to learners why the chosen option is incorrect?
2. Question 02 of the test: the correct answer is (A)
   2.1. Which wrong option do you expect your learners to choose?
   2.2. Why do you think they will choose this option?
   2.3. How would you explain to learners why the chosen option is incorrect?
3. Question 03 of the test: the correct answer is (A)
   3.1. Which wrong option do you expect your learners to choose?
   3.2. Why do you think they will choose this option?
   3.3. How would you explain to learners why the chosen option is incorrect?
4. Question 04 of the test: the correct answer is (A)
   4.1. Which wrong option do you expect your learners to choose?
   4.2. Why do you think they will choose this option?
   4.3. How would you explain to learners why the chosen option is incorrect?
5. Question 05 of the test: the correct answer is (A)
   5.1. Which wrong option do you expect your learners to choose?
   5.2. Why do you think they will choose this option?
   5.3. How would you explain to learners why the chosen option is incorrect?
6. Question 06 of the test: the correct answer is (A)
   6.1. Which wrong option do you expect your learners to choose?
   6.2. Why do you think they will choose this option?
   6.3. How would you explain to learners why the chosen option is incorrect?
7. Question 07 of the test: the correct answer is (A)
   7.1. Which wrong option do you expect your learners to choose?
   7.2. Why do you think they will choose this option?
   7.3. How would you explain to learners why the chosen option is incorrect?
8. Question 08 of the test: the correct answer is (A)
   8.1. Which wrong option do you expect your learners to choose?

8.2. Why do you think they will choose this option?

8.3. How would you explain to learners why the chosen option is incorrect?

9. Question 09 of the test: the correct answer is (A)

   9.1. Which wrong option do you expect your learners to choose?

   9.2. Why do you think they will choose this option?

   9.3. How would you explain to learners why the chosen option is incorrect?

10. Question 10 of the test: the correct answer is (A)

   10.1. Which wrong option do you expect your learners to choose?

   10.2. Why do you think they will choose this option?

   10.3. How would you explain to learners why the chosen option is incorrect?

APPENDIX 3: PARTICIPANT INFORMATION SHEET

UNISA university of south africa

PARTICIPANT INFORMATION SHEET

06 FEBRUARY 2024

Title: **Exploring Science Teachers' Strategies for Addressing Misconceptions about Electric Circuits**

DEAR PROSPECTIVE PARTICIPANT

My name is Malesela Aaron Phifadi and I am doing research under the supervision of Dr. EN Mazibe, a senior lecturer in the Department of Science and Technology Education towards Master of Education at the University of South Africa. We have funding from UNISA Postgraduate Bursaries for the Master's Dissertation. We are inviting you to participate in a study entitled Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study.

WHAT IS THE PURPOSE OF THE STUDY?

This study is expected to collect important information that could explore teachers' awareness of learners' misconceptions in electric circuits, planned strategies for addressing the misconceptions and how they actually address the misconceptions when giving feedback to learners after writing a test designed to elicit misconceptions in electric circuits.

WHY AM I BEING INVITED TO PARTICIPATE?

You are invited because you teach Physical Science in grade 11 where the topic of electric circuits is taught. I obtained your contact details from your school principal. The study will involve three participants from three different schools.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

The study involves a semi-structured interview and lesson observations. During the interview, an audio recorder will be used to information. You will be asked 10 questions, aiming to get your perspective on misconceptions learners have about electric circuits. The duration of the interview will be approximately 45 to 60 minutes but, the length of observation will be determined by the lesson as per your school timetable.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you decide to take part in this study, you will be given this information sheet to keep and asked to sign a written consent form. You are free to withdraw at any time and without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

The benefits of this study are to explore teachers' awareness of learners' misconceptions in electric circuits, planned strategies for addressing the misconceptions and how they actually address the misconceptions when giving feedback to learners after writing a test designed to elicit misconceptions in electric circuits.

ARE THERE ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

This study is a medium risk study, because the lesson observation will involve the learners below the age of 18 years which may be discomforting to them. However, the study will collect information that will be regarded as non-sensitive, such as opinion rather than personal information.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

Your name will not be recorded anywhere and that no one, apart from the researcher and identified members of the research team, will know about your involvement in this study and no one will be able to connect you to the answers you give. Your answers will be given a code number or pseudonym, and you will be referred to this way in the data, any publications, or other research methods, such as conference proceedings.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

The anonymous data may be used for other purposes, such as, research report, journal articles and/or other proceedings. The privacy of the data will maintain confidential and anonymous. Hardcopies of your answers will be stored by the researcher for a period of five years in a locked cabinet at home in my office for future research or academic purposes, electronic information will be stored on a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. If necessary, hardcopies will be shredded, and electronic copies will be permanently deleted from the computer.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

No payment or any incentive will be given for participating in this study.

HAS THE STUDY RECEIVED ETHICS APPROVAL

This study has received written approval from the Research Ethics Review Committee of UNISA. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the research findings, please contact Phifadi Malesela Aaron at 0818171923 or 56931514@mylife.unisa.ac.za. The findings are accessible for one year. Should you require any information or want to contact the researcher about any aspect of this study.

Should you have concerns about the way in which the research is conducted, you may contact:

Dr. Mazibe, E.N

Email: maziben@unisa.ac.za

Thank you for taking the time to read this information sheet and participating in this study.

PHIFADI MALESELA AARON (Researcher)

APPENDIX 4A: INTERVIEW TRANSCRIPT FOR MR. NM

INTERVIEW TRANSCRIPT: MR. NM

INTERVIEWER: My name is Phifadi Malesela Aaron, a researcher from the University of South Africa for a master's in education in the department of Science and Technology Education. The study explores **Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits.** You are reminded of your rights to participate or not participate in this study, meaning that participation is voluntary. I also thank you before we start for allowing me to hear your insight about different aspects as in the research questions.

INTERVIEWEE: alright

INTERVIEWER: Interview with Teacher Y. Do you consent to this interview and are you aware that the data collected from this interview will be used for research purposes?

INTERVIEWEE: Yes, i am aware and consent.

INTERVIEWER: Every question starts by a typical test item for learners in a box. You are not required to answer the items in the box. You are required to answer the questions following the boxed items. Note that the correct option of each item is given. You are required to think about mistakes that your learners would make had they been given these test items.

INTERVIEWEE: Yes

INTERVIEWER: For item number 1, the question was, why does a bulb light up when connected in a circuit? You were told that the correct answer was A, which said electrical energy is converted to light and you were asked which wrong option do you expect your learners to choose, and you said they will choose option C, which said that electrical current is converted to light. Why do you think they will choose this option?

INTERVIEWEE: I think learners will choose letters C, because if you can check A is about electrical energy, and B is electrical charge and C is a current. So learners will think that maybe for a bulb to light up is because of the current that is flowing through the circuit. That is what I think learners will take it that way.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: On how I will explain to learners for choosing the incorrect option, I will use the definition for electrical energy, the definition for electric charge and the definition for electrical current. In that way I will be interpreting them, I will be interpreting what is an electric energy? What is an electric charge? And what is an electric current? And their function on the circuit so that the learners now can be able to see what makes the bulb to light up.

INTERVIEWER: For item number 2, the question was, how do currents at point x and y compare? You were told that the correct answer was A which said current at x is equal to current at y, and you were asked which wrong option do you expect your learners to choose, and you said they will choose option B, which said that current at x is greater than current at y. Why do you think they will choose this option?

INTERVIEWEE: In think the learners will choose option B, looking at the flow of that current, current flowing from x is going to pass through the bulb, then when it has passed through the bulb, it means some of the current are going to remain at that bulb and when it reaches y it has been decreased. That is my thinking.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: Ya, also by the definition of the current and the explanation of how the current flow, especially when the current flow passing through resistor or light bulb, that what happens to that current, so that the learner can see that the very same current that was flowing from x is the same current that is flowing at that point y.

INTERVIEWER: For item 3, the question was, which diagram correctly represents the flow of conventional current in the circuit? You were told that the correct answer was A which said that conventional current flows from positive terminal to the negative terminal, and you were asked which wrong option do you expect your learners to choose? And you said they will choose option D, which said that conventional current flows from negative terminal to positive terminal. Why do you think they will choose this option?

INTERVIEWEE: Yes, I think learners will choose option D because they will take it in the sense that current is flowing from small terminal to big terminal, it is about the flowing from which terminal. They will think maybe it is flowing from small terminal to big terminal. That is what I think the learners will think.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: On how will explain to the learners for the chosen option, by giving them an example of the cell or battery, like I will take a battery, because on the battery we have a positive side and also the negative side, and also introduce this conventional current. That on the conventional current, the current will be flowing from the positive to the negative. And then how do we see that this one is a positive and this one is a negative on the circuit? On the circuit, the big terminal, current will be flowing from the big terminal to the smaller terminal, meaning that the big terminal will be representing the positive and the small terminal will be representing the positive.

INTERVIEWER: For item 4, the question was, which bulb or bulbs are the least bright? You were told that the correct answer was A which said that bulb y and z are the least bright, and you were asked which wrong option do you expect your learners to choose? And you said they will choose B, which said that bulbs y, z, v and w will be the least bright. Why do you think they will choose this option?

INTERVIEWEE: I think learners will choose option B, looking into the question of saying the bulb or the bulbs are the least bright, taking that B is a bulb y, z, v and w, meaning that there are more bulb on the circuit, meaning that they will share all the volts that is on the circuit. All of them will be least bright.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: To explain to learners, I will be using the series connection and the parallel connection. So that the learners can understand on how the brightness of the bulb is coming from or it depends, showing them on how the brightness of the series and the brightness of the parallel and on the series we are just having just one bulb and on the parallel we have two or more in the connection of the parallel, looking into how the brightness of the bulb behaves.

INTERVIEWER: For item number 5, the question was, how does the brightness of the light bulbs change if the switch is closed? You were told that the correct answer was A which said that bulb y is brighter, and bulb x is zero, and you were asked which wrong option do you expect your learners to choose. You said that you expect your learners to choose option E which said there is no difference in brightness of the light bulbs. Why do you think they will choose this option?

INTERVIEWEE: I think the learners will choose option E, in a sense that bulb x and bulb y are of the same resistance and the current will be flowing through x and y is the same. Meaning they will have the same brightness. Because they will be sharing the same potential difference, because we are having two equal resistors. By assuming that they have equal resistance, there will be no difference in brightness.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: By using the short circuit. Meaning that if I closed the switch, it means that I am blocking current from flowing to that bulb x, because as the current flows through the circuit, it going to be resisted from flowing to x, then all the current will be flowing to bulb, making bulb to be bright because it is getting the full voltage.

INTERVIEWER: For item 6, the question was, A 6 V battery is connected to a bulb as shown above in the diagram. A voltmeter is the connected between P and S. Next it is connected between P and Q, then Q and T and finally T and S. what are the voltmeter readings between the various points? You were told that the correct answer was A which said that the voltmeter readings for PS is 6, for PQ is 0, for QT is 6 and for TS is 0, and you ware asked which wrong option do you expect your learners to choose. You said that you expect your learners to choose option B which said that the voltmeter readings for all points is 6. Why do you think they will choose this option?

INTERVIEWEE: I think the learners will choose option B, because we are talking about voltmeter, meaning that, that voltmeter is connected to that circuit and is the one that is all over the circuit. That is why I said at point PS the voltage will be the same PQ, the same as PT, the same as TS. That is what I think the learners will choose.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: To explain to the learners, I will use the definition for the voltage and the definition for the current and which one is flowing through the circuit between the voltage and the current, because we know that the only thing that is flowing is the current, and that current is transporting that voltage to the bulb. So the only voltage that is going to exist is at point QT.

INTERVIEWER: For item number 7, the question was, what happens to the brightness of the bulbs X and Y if we add a resistor between them? You were told that the correct answer was A which said that bulb X and Y are both less bright, and you were asked which option do you expect your learners to choose. You said that you expect your learners to choose option C, which said that bulb X is less bright and y is unchanged. Why do you think they will choose this option?

INTERVIEWEE: I think learners will choose option C which says X will be less bright and Y unchanged, because introducing a new resistor between Y and X, because the current will be flowing into bulb Y and into that resistor, so once it reaches X it will be less.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: Using the series connection, on how the bulbs connected in series share the voltage.

INTERVIEWER: For item number 8, the question was, how do the readings on the ammeters X and Y change if the switch is closed? You were told that the correct answer was A which said that the reading on X increases and on Y remain unchanged, and you were asked which option do you expect your learners to choose. You said that you expect your learners to choose option D which said that the reading on both X and Y decreases. Why do you think they will choose this option?

INTERVIEWEE: I think they will choose option D because, like now switch is closed, meaning that the current in Y will be shared with the bulb Q resulting in a decrease in the original current at Y. Also affecting the ammeter X to increase.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: I will use Ohm's law, whereby, the total resistance of the circuit as it is increasing, the current of the circuit will decrease.

INTERVIEWER: thank you once more, Sir for your time. It was a pleasure interacting with you, I thank you.

APPENDIX 4B: INTERVIEW TRANSCRIPT FOR MR. MT

<u>**INTERVIEW TRANSCRIPT: MR. MT**</u>

INTERVIEWER: my name is Phifadi Malesela Aaron, a researcher from University of South Africa for master's in education in the department of Science and Technology Education. The study explores **Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits.** You are reminded of your rights to participate or not participate in this study, meaning that participation is voluntary. I also thank you before we start for giving me the opportunity to hear your insight about different aspects as in the research questions.

INTERVIEWEE: alright.

INTERVIEWER: interview with participant 1. Do you consent to this interview and are you aware that the data collected from this interview will be used for research purposes?

INTERVIEWEE: yes, I consent, and I am aware that the data collected in this interview will be used for research purposes.

INTERVIEWER: Every question starts by a typical test item for learners in a box. You are not required to answer the items in the box. You are required to answer the questions following the boxed items. Note that the correct option of each item is given. You are required to think about mistakes that your learners would make had they been given these test items.

INTERVIEWEE: ok.

INTERVIEWER: For item number 1, on the questionnaire you indicated that your learners will choose option C, which says electrical current is converted into light. Why do you think they will choose this option?

INTERVIEWEE: because I think learners will think that electrical current, aker, is the one that is converted to a light. They will not think of what? Energy, because I think if we talk about energy, energy is the one that can be converted to a light. But I think they will think about electrical current to be the one to be converted to a what?, to a light.

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: I will explain to them that electrical energy, it can be converted to either to a light or to a heat, but in this instance, we are talking about, what, to a light. When we talk about to a light, is such that electrical energy is the one that can be converted to a light, not electrical current, the energy is the one that can be converted to a light.

Interview: For item 2, on the questionnaire indicated that you expect them to choose B, which says that x > y, why do you think they will choose this option?

INTERVIEWEE: because I think maybe they will just think that current is flowing anticlockwise, where it is going to start from x. so they expect to get more current point x than in point y. that is why I will say the learners might choose option B.

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: that the current is the same. As the current is moving, it is anticlockwise. So same current that is measured at point x is the same as the current measured at point y.

INTERVIEWER: In item 3, you indicated that your learners might choose D. Why do you think they might choose this option?

INTERVIEWEE: I just think that they will think that current is going to flow clockwise.

INTERVIEWER: so which means that the learners would know how conventional current flow. Because in option A the current flows from positive to negative, but in option D it is the other way round.

INTERVIEWEE: the other way round, yes

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: that conventional current, it moves from positive to negative. They need to know that conventional current moves from positive to negative.

INTERVIEWER: for item 4, you indicated that your learners will choose E, which says z and w. why do you think they will choose this option?

INTERVIEWEE: because since the current is flowing, I think it is going to flow anticlockwise. If you can look, for x is only this option, but for y and z, they will expect more current to be at y than in z. then, same applies this one ya the parallel connection as well, because, current will be starting from v to w, where the last one I expect them to say it is going to be the least bright, this z and w is going to be the least bright.

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: ok, for the first circuit, the voltage at x is going to be the same voltage because it is only one bulb. But for this one, the second one, y and z, they are connected in series, they are going to divide the potential difference. When the potential difference is divided among y and z, there is going to be less bright, because potential difference is directly proportional to energy, I think that will be the answer.

INTERVIEWER: for item 5, you indicated that you expect them to choose B, why do you think that they will choose this option?

INTERVIEWEE: because I think that they will think that the two bulbs are connected in series, where current is going to be the same. They expect same current to be at x and y, because it is connected in series and the switch is now closed. The current that flows at x must the same as the current at y.

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: I will say that since the circuit is connected in series, when it is connected in series, y is going to be brighter. Because since the circuit now is closed, the current will flow passing point, it will no longer go to x, the only, like the potential difference that we have, is going to the same as the potential difference that we have at y. since potential difference is directly proportional to the energy. That means y will be brighter since our x is going to be a shorter circuit.

INTERVIEWER: for item 6, you indicated that you expect your learners choose option B. why do you think they will choose this option?

INTERVIEWEE: because the voltage is connected in parallel, and we know that in a parallel combination, the potential difference is the same. That is why we are choosing option B. where we say, if from PS is 6 , from QP it must also be 6, then from QT it must be 6, even from ST it must be 6.

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: potential difference is connected in parallel to the first one, between T and S to the battery. When it is connected in parallel to the battery, it must measure 6 volts. The total voltage of the battery. Also from Q to T, it must be connected in parallel to the resistor where it must also measure 6. The from P and Q, even if we connect it in parallel, it cannot read anything, because it is not connected to either the battery or resistor, there is no resistor between P and Q. same as apply to S and T.

INTERVIEWER: for item 7, you indicated that your learners will choose is C. why do you think they will choose this option?

INTERVIEWEE: I think they will choose C because they will think that if a resistor is been put between y and x, less brightness will be in x than in y or y will remain unchanged as current flows anticlockwise, where they will think that the current that will be at y is going to change before it passes to x. the resistor will affect the current to change to be less bright.

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: because since this circuit is connected in series, we expect the potential difference to divide, that means if the total potential difference is 12 V, we expect to get 6 in both x and y. but if we add a resistor, the potential difference is going to be more divided. They have to share that 12 among the three , that means they are going to be less bright.

INTERVIEWER: for item 8, you indicated that your learners might choose C, that says x decreases and y also decreases. Why do you think they will choose this option?

INTERVIEWEE: since the circuit is going to be closed, I expect that the current in x is going to decrease, why because x is connected to q in series, where the current is the same. Since p and q are connected in parallel, I expect that the current to divide, the divided current at p is going to be the same as the one at y.

INTERVIEWER: how would you explain to learners that the chosen option is incorrect?

INTERVIEWEE: when the switch is closed, x will read the total current of the circuit. When the switch is closed, the current at y is going to remain unchanged. Then the current at x is going to increase, why the current increases, because we are adding more resistors in parallel. When we add more resistors in parallel, the current is going to increase.

INTERVIEWER: thank you once more, Sir for your time. It was a pleasure interacting with you, I thank you.

APPENDIX 4C: INTERVIEW TRANSCRIPT FOR Ms. RM

INTERVIEW TRANSCRIPT: Ms. RM

INTERVIEWER: My name is Phifadi Malesela Aaron, a researcher from the University of South Africa for a master's in education in the department of Science and Technology Education. The study explores **Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits.** You are reminded of your rights to participate or not participate in this study, meaning that participation is voluntary. I also thank you before we start for allowing me to hear your insight about different aspects as in the research questions.

INTERVIEWEE: Okay

INTERVIEWER: Interview with Teacher Y. Do you consent to this interview and are you aware that the data collected from this interview will be used for research purposes?

INTERVIEWEE: Yes, I do

INTERVIEWER: Every question starts by a typical test item for learners in a box. You are not required to answer the items in the box. You are required to answer the questions following the boxed items. Note that the correct option of each item is given. You are required to think about mistakes that your learners would make had they been given these test items.

INTERVIEWEE: Ok

INTERVIEWER: For item number 1, the question was, why does a bulb light up when connected in a circuit? You were told that the correct answer was A, which said electrical energy is converted to light and you were asked which wrong option do you expect your learners to choose, and you said they will choose option C, which said that electrical current is converted to light. Why do you think they will choose this option?

INTERVIEWEE: the reason for choosing option C, I think it will be on the fact that when there is current flowing, or when the light bulb is on, or is heated up, they believe that we are now having electric current. So their idea might be that when the current enters the certain resistor or light bulb, it is the one that is being converted to the light, not necessarily the energy, the electrical energy being converted to the light but the current.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: alright, reason being, when we are having a certain circuit, there is a transfer or conversion of energy, not necessarily conversion of electrons. So with that being said, it means that when you are plugging a circuit, in essence, learners will believe that we having an electricity being connected, having that electricity, we are not converting the current when it enters a certain circuit or it enters a certain bulb. It is the energy being released by the battery that is going to be converted to the light, not necessarily the current, the current is just being pushed through the conductor, but then what is being converted is the electrical energy from the battery, converted to the light energy. That will be the result of light being lit up.

INTERVIEWER: For item number 2, the question was, how do currents at point x and y compare? You were told that the correct answer was A which said current at x is equal to current at y, and you were asked which wrong option do you expect your learners to choose, and you said they will choose option C, which said that current at x is greater than current at y. Why do you think they will choose this option?

INTERVIEWEE: The reason for choosing option C was on the basis that they know that electrons move from a negative terminal to a positive terminal. So the idea might be that maybe the y is going to carry more of the electrons, so having to carry more of the electrons might take more from the one that is going to leave x, so resulting in x having less electrons. That is why I chose y is greater than x.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: When we are dealing with a circuit, we are having two, so when we are having a series circuit, in terms of its current, since it is a single path from one end to another, the current that enters is the same. So everywhere, throughout the whole circuit, the current is the same in a series circuit.

INTERVIEWER: For item 3, the question was, which diagram correctly represents the flow of conventional current in the circuit? You were told that the correct answer was

A which said that conventional current flows from positive terminal to the negative terminal, and you were asked which wrong option do you expect your learners to choose? And you said they will choose option D, which said that conventional current flows from negative terminal to positive terminal. Why do you think they will choose this option?

INTERVIEWEE: they know that electrons move from a negative terminal to a positive terminal, however, the conventional current is the one that is moving from positive terminal to the negative terminal, so choosing D will be as a result of the motion of electrons, not necessarily the motion of current.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: I will mention that the one that move from negative to positive it is the electron. But the conventional current is the one that moves from the positive terminal to the negative terminal. That is why option D cannot be the correct answer.

INTERVIEWER: For item 4, the question was, which bulb or bulbs are the least bright? You were told that the correct answer was A which said that bulb y and z are the least bright, and you were asked which wrong option do you expect your learners to choose? And you said they will choose D, which said that bulbs y, z, v and w will be the least bright. Why do you think they will choose this option?

INTERVIEWEE: I chose D, reason being that, the knowledge that they have of parallel circuit, saying that in a parallel circuit current is divided. So with them understanding that for us to have a certain flow, we need a current. So they might think that, having a parallel circuit and also having current as being divided, being divided in those different resistors or different bulbs is going to lead to a dimmer light because it is not the same as the one being carried in a series circuit.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: In terms of explaining, I will mention that in a parallel circuit, both bulbs have the same voltage. And then, when we look at Ohm’s law, it says potential difference is directly proportional to the current. So if we are having resistors that are connected in parallel, they are going to carry the same potential difference from the battery. So having that same potential difference, they are also going to have a greater current, resulting in a higher brightness of the bulbs.

INTERVIEWER: For item number 5, the question was, how does the brightness of the light bulbs change if the switch is closed? You were told that the correct answer was A which said that bulb y is brighter, and bulb x is zero, and you were asked which wrong option do you expect your learners to choose. You said that you expect your learners to choose option B which said there is no difference in brightness of the light bulbs. Why do you think they will choose this option?

INTERVIEWEE: In essence, they will say, they are both connected in series. I think also it be because of not knowing that when you are having such kind of a circuit, it might look like it is parallel, however, the minute when close the switch it means we are going to have an easier way for the circuit. They might think that we are going to have a series circuit, because the understanding of a parallel circuit will be a bit complicated because they will just think it is still connected in a series circuit.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: In essence, I will say to clarify that idea to say, if you check, in this circuit, at first we were having a series circuit, we were having a series circuit, but the minute we close the switch, we are now cutting the other one outside, because it is not going to form a parallel circuit. It is forming an easier way for the flow of current.

INTERVIEWER: For item 6, the question was, A 6 V battery is connected to a bulb as shown above in the diagram. A voltmeter is the connected between P and S. Next it is connected between P and Q, then Q and T and finally T and S. what are the voltmeter readings between the various points? You were told that the correct answer was A which said that the voltmeter readings for PS is 6, for PQ is 0, for QT is 6 and for TS is 0, and you ware asked which wrong option do you expect your learners to choose. You said that you expect your learners to choose option B which said that the voltmeter readings for all points is 6. Why do you think they will choose this option?

INTERVIEWEE: I think when they look at this circuit, and they say we are moving the measure of voltage which is the voltmeter from this point to another corner, to another corner, they might think that throughout the whole conductor, we are having the same voltage. That is why I am saying they will choose B, that is why it is 6 throughout.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: to clarify this, I will say, when we move from P to S, P to S we are measuring the voltage of the battery, when we move from P to Q, we are only having the conductor, that is why we are having zero. When we move from Q to T, we are having a resistor, as long as we are having a resistor, that resistor is going to give us a certain voltage, it is not just a single conductor, but it is a resistor. Same thing with on the other side of P and Q, and ST is just a conductor that we are measuring, nothing else. But on the other side, we are measuring the voltage of the battery and then we are also going to measure the voltage of the bulb on the other side.

INTERVIEWER: For item number 7, the question was, what happens to the brightness of the bulbs X and Y if we add a resistor between them? You were told that the correct answer was A which said that bulb X and Y are both less bright, and you were asked which option do you expect your learners to choose. You said that you expect your learners to choose option D, which said that bulb X is less bright and y is unchanged. Why do you think they will choose this option?

INTERVIEWEE: I am saying it is D because of the notion that they have concerning electric circuits. That if we were going to have connection in series circuit, the current is the same, having the current the same, it means that they are going to have the same brightness.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: when we clarify it, we say, when we are adding another bulb in a series circuit, we are increasing the resistance. When we increase the resistance, resistance is inversely proportional to the current. So increasing the resistance, decreases the current. That is how I will clarify it.

INTERVIEWER: For item number 8, the question was, how do the readings on the ammeters X and Y change if the switch is closed? You were told that the correct answer was A which said that the reading on X increases and on Y remain unchanged, and you were asked which option do you expect your learners to choose. You said that you expect your learners to choose option D which said that the reading on both X and Y decreases. Why do you think they will choose this option?

INTERVIEWEE: I chose D because they will think that before we had a series circuit, closing the switch, we are in a way, opening a different path, they are then going to say that one in series is going to increase, but then when it gets here it is going to split. That is why they might say that now, because of the division, it is now going to decrease. That is why I am saying that they are going to choose D, because they will think that one is increasing and this one is decreasing, because we are having parallel as current divider.

INTERVIEWER: How would you explain to your learners why the chosen option is incorrect?

INTERVIEWEE: To explain, I will say that, when we first had a series circuit, the series circuit was only connected to one resistor, meaning that the total potential difference that is in the battery is going to be the same one that is in the resistor. When we are going to connect another light bulb in a parallel circuit, we are not going to change the voltage. And again, mind you, the resistor has not changed, so as a result, if we want the current of letter Y, we are still having the same resistor and we are still having the same potential difference, and if we check, it is going to result as having the same current at point Y. So X is increasing as a result of having a new total equivalent resistance

INTERVIEWER: thank you once more, Sir for your time. It was a pleasure interacting with you, I thank you.

APPENDIX 5: LETTER TO DISTRICT REQUESTING PERMISSION

UNISA university of south africa

Request for permission to conduct research at secondary schools under Capricorn South District

Title: Exploring Science Teachers' Strategies for Addressing Misconceptions In Electric Circuits

06 FEBRUARY 2024

The District Director

Capricorn South District

Tell:

Dear Madam

I, Malesela Aaron Phifadi, am doing research under the supervision of Dr. EN Mazibe, a senior lecturer in the Department of Science and Technology Education towards an M.Ed in Natural Science Education at the University of South Africa. I am requesting your permission to conduct research at secondary schools in Moletlane circuit. The study is titled **Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study.**

The aim of the study is to explore teachers' awareness of learners' misconceptions in electric circuits, planned strategies for addressing the misconceptions and how they actually address the misconceptions when giving feedback to learners after writing a test designed to elicit misconceptions in electric circuits. The schools have been selected because they have teachers who teach physical science in grade 11 where the topic of electric circuits is taught. The study will entail requesting teachers to participate in a face-to-face interview, administration of a conceptual understanding test to their learners and an in-classroom observation when they give feedback of the test to their learners.

The research results may help schools to find effective teaching strategies that can address misconceptions and improve learners' understanding of electric circuits. There are no risks involved in participating in this research. There will be no reimbursement or any incentives for participation in the study.

The feedback procedure will entail the submission of the research report to the district office.

Yours sincerely

Phifadi Malesela Aaron

Researcher

Cell phone number: 081 817 1923

Email: 56931514@mylife.unisa.ac.za

APPENDIX 6: LETTER TO CIRCUIT REQESTING PERMISSION

Request for permission to conduct research at secondary schools under Moletlane circuit.

Title: Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study

06 FEBRUARY 2024

The Circuit Manager

Moletlane Circuit Office

Tell:

Dear Sir

I, Malesela Aaron Phifadi, am doing research under the supervision of Dr. EN Mazibe, a senior lecturer in the Department of Science and Technology Education towards a Master of Education in Natural Science Education at the University of South Africa. I am requesting your permission to conduct research at secondary schools in Moletlane circuit. The study is titled **Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study**.

The aim of the study is to explore teachers' awareness of learners' misconceptions in electric circuits, planned strategies for addressing the misconceptions and how they actually address the misconceptions when giving feedback to learners after writing a test designed to elicit misconceptions in electric circuits. The schools have been selected because they have teachers who teach physical science in grade 11 where the topic of electric circuits is taught. The study will entail requesting teachers to participate in a face-to-face interview, administration of a conceptual understanding test to their learners and an in-classroom observation when they give feedback of the test to their learners.

The research results may help schools to find effective teaching strategies that can address misconceptions and improve learners' understanding of electric circuits. There are no risks involved in participating in this research. There will be no reimbursement or any incentives for participation in the study.

The feedback procedure will entail the submission of the research report to the circuit office.

Yours sincerely

Phifadi Malesela Aaron

Researcher

Cell phone number: 081 817 1923
Email: 56931514@mylife.unisa.ac.za

APPENDIX 7: LETTER TO SCHOOLS REQUESTING PERMISSION

UNISA university of south africa

Request for permission to conduct research at ____________________ Secondary School

Title: Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study

06 FEBRUARY 2024

The Principal

_________________ Secondary School

Tell:

Dear Sir

I, Malesela Aaron Phifadi, am doing research under the supervision of Dr. EN Mazibe, a senior lecturer in the Department of Science and Technology Education towards an Master of Education in Natural Science Education at the University of South Africa. I am requesting your permission to conduct research at secondary schools in Moletlane circuit. The study is titled **Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study**.

The aim of the study is to explore teachers' awareness of learners' misconceptions in electric circuits, planned strategies for addressing the misconceptions and how they actually address the misconceptions when giving feedback to learners after writing a test designed to elicit misconceptions in electric circuits. The schools have been selected because they have teachers who teach physical science in grade 11 where the topic of electric circuits is taught. The study will entail requesting teachers to participate in a face-to-face interview, administration of a conceptual understanding test to their learners and an in-classroom observation when they give feedback of the test to their learners.

The research results may help schools to find effective teaching strategies that can address misconceptions and improve learners' understanding of electric circuits. There are no risks involved in participating in this research. There will be no reimbursement or any incentives for participation in the study.

The feedback procedure will entail the submission of the research report to the school.

Yours sincerely

____

Phifadi Malesela Aaron

Researcher

Cell phone number: 081 817 1923
Email: 56931514@mylife.unisa.ac.za

APPENDIX 8: PARTICIPANT CONSENT FORM

CONSENT/ASSENT TO PARTICIPATE IN THIS STUDY (Return slip)

I, ____

(participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the **Semi- structured interview and classroom observations.**

I have received a signed copy of the informed consent agreement.

Participant Name & Surname (please print)

____

Participant Signature Date

Researcher's Name & Surname (please print)

____

______________________ 17/04/2024

Researcher's signature Date

APPENDIX 9: PARENT CONSENT FORM

UNISA university of south africa

Parental consent and learner's Assent

Dear Parent

Your _____________ is invited to participate in a study entitled Exploring Science Teachers' Strategies for Addressing Misconceptions about Electric Circuits

I am undertaking this study as part of my master's research at the University of South Africa. The purpose of the study is to explore teachers' awareness of learners' misconceptions in electric circuits, planned strategies for addressing the misconceptions and how they actually address the misconceptions when giving feedback to learners after writing a test designed to elicit misconceptions in electric circuits and the possible benefits of the study are the improvement of an improved way of teaching and learning the concepts of electric circuits. I am asking permission to include your child in this study because he/she is doing physical science in grade 11 where the topic of electric circuits is taught. I expect to have ___________other children participating in the study.

If you allow your child to participate, I shall request him/her to:

- Complete a test and
- Be observed when the teacher will be giving feedback for the test.

Any information that is obtained in connection with this study and can be identified with your child will remain confidential and will only be disclosed with your permission. His/her responses will not be linked to his/her name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only.

There are no foreseeable risks to your child by participating in the study. Your child will receive no direct benefit from participating in the study; however, the possible benefits to education are improved comprehension of electric circuits concepts. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect him/her in any way. Similarly, you can agree to allow your child to be in the study now and change your mind later without any penalty.

The study will take place during regular classroom activities with the prior approval of the school and your child's teacher. However, if you do not want your child to participate, an alternative activity will be available, in the form of a separate class test.

In addition to your permission, your child must agree to participate in the study and you and your child will also be asked to sign the assent form which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password locked computer in my locked office for five years after the study. Thereafter, records will be erased.

The benefits of this study are improved comprehension of electric circuits concepts and correction of misconceptions.

There are no risks associated with this study.

There will be no reimbursement or any incentives for participation in the research.
If you have questions about this study please ask me or my study supervisor, Dr. Mazibe E.N Department of Science and Technology Education at the College of Education, University of South Africa. My contact number is 0818171923 and my e-mail is 56931514@mylife.unisa.ac.za. The e-mail of my supervisor ismaziben@unisa.ac.za. Permission for the study has already been given by District Director, Circuit Manager and Principal, and the Ethics Committee of the College of Education, UNISA.

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child:

Sincerely

________________________________ ______________________________ _________________

Parent/guardian's name (print) Parent/guardian's signature: Date:
MALESELA AARON PHIFADI__ _________________
08/02/2024
Researcher's name (print) Researcher's signature Date:

____

LETTER REQUESTING ASSENT FROM A LEARNER TO PARTICIPATE IN A RESEARCH PROJECT

Title: Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study

Dear ___________ Date ________________

I am doing a study on Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study as part of my studies at the University of South Africa. Your principal has given me permission to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find ways that your teachers can use to teach better. This may help you and many other learners of your age in different schools.

This letter is to explain to you what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of these words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study.

I would like to ask you complete a test on electric circuits. Answering the test will take no longer than 30 minutes.

I will write a report on the study, but I will not use your name in the report or say anything that will let other people know who you are. Participation is voluntary and you do not have to be part of this study if you don't want to take part. If you choose to be in the study, you may stop taking part at any time without penalty. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

The benefits of this study are improved comprehension of electric circuits concepts and correction of misconceptions.

There are no risks associated with this study.

You will not be reimbursed or receive any incentives for your participation in the research.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can have your parent or another adult call me at 0818171923. Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher: MALESELA AARON PHIFADI Phone number: 0818171923

Do not sign the written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

WRITTEN ASSENT

I have read this letter which asks me to be part of a study at my school. I have understood the information about my study and I know what I will be asked to do. I am willing to be in the study.

___________________________ _______________________ _______________________

Learner's name (print): Learner's signature: Date:

___________________________ _________________________ _______________________

Witness's name (print) Witness's signature Date:

(The witness is over 18 years old and present when signed.)

___________________________ ___________________________ ______________________

Parent/guardian's name (print) Parent/guardian's signature: Date:

MALESELA AARON PHIFADI  **2024/02/13**

Researcher's name (print) Researcher's signature: Date:

APPENDIX 11: ETHICAL CLEARANCE CERTIFICATE

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2024/03/13

Ref: **2024/03/13/56931514/15/AM**
Name: Mr MA Phifadi
Student No.:56931514

Dear Mr MA Phifadi

Decision: Ethics Approval from 2024/03/13 to 2027/03/13

Researcher(s): Name: Mr MA Phifadi
E-mail address: 56931514@mylife.unisa.ac.za
Telephone: 081 817 1923

Supervisor(s): Name: Dr. EN Mazibe
E-mail address: maziben@unisa.ac.za
Telephone: N/A

Title of research:

Exploring Science Teachers' Strategies for Addressing Student Misconceptions about Electric Circuits: A Qualitative Study

Qualification: MEd Natural Science Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2024/03/13 to 2027/03/13.

*The **medium risk** application was reviewed by the Ethics Review Committee on 2024/03/13 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the UNISA College of Education Ethics Review Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
8. No field work activities may continue after the expiry date **2027/03/13**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2024/03/13/56931514/15/AM** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Kind regards,

Prof AT Motlhabane
CHAIRPERSON: CEDU RERC
motlhat@unisa.ac.za

Prof Mpine Makoe
EXECUTIVE DEAN
qakisme@unisa.ac.za

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APPENDIX 12: APPROVAL FROM LIMPOPO DEPARTMENT OF EDUCATION

Confidential Information - This is for official consumption

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

Ref: 2/2/2 Enquiries: Makola MC Tel No: 015 290 9448 E-mail: MakolaMC@edu.limpopo.gov.za

Phifadi MA
Private Bag X522
Koringpunt
0632

5631514@mylife.unisa.za

RE: REQUEST TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal reads as follows: **EXPLORING SCIENCE TEACHERS' STRATEGIES FOR ADDRESSING STUDENT MISCONCEPTIONS ABOUT ELECTRIC CIRCUITS: A QUALITATIVE STUDY**
3. The following conditions should be considered:

3.1 The research should not have any financial implications for Limpopo Department of Education.

3.2 Arrangements should be made with the Circuit Office and the School concerned

3.3 The conduct of research should not in any how disrupt the academic programmes at the school(s)

3.4 The research should not be conducted during the time of Examinations especially in the fourth term

3.5 During the study, applicable research ethics should be adhered to; in particular the principle of voluntary participation (the people involved should be respected and treated with dignity)

Cnr. 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X9489, POLOKWANE, 0700
Tel: 015 290 7600 • Fax: 015 297 6920/4220/4494

***The heartland of South Africa** – Development is about people!*

3.6 Upon completion of the research, the researcher shall share the final product of the research with the Department.

4 Additionally, you are expected to produce this letter at School(s)/Office(s) where you intend to conduct your research as evidence that permission has been granted for access to the research site(s).

5 The Department appreciates the contribution that you wish to make and wishes you success in your investigation

Best wishes

....   15/04/2024

MC Makola PhD   **Date**

....   16/04/2024

Molope NM   **Date**

Acting DDG: Corporate Management

APPENDIX 13: EDITOR CERTIFICATE

STMbondvo editing services (Pty) Ltd

148 Aramburg (Mpumalanga) Cell: 060 346 7091 email:mhlekazist@gmail.com

<u>Proof of editing</u>

STMbondvo editing services
148 Aramburg
Mpumalanga
South Africa
Cell.: 0603467091

Date: 22 April 2025

This is to certify that I have edited the dissertation of the following candidate:

Names and Surname: M. A Phifadi

Student number: 56931514

Title: Exploring science teachers' strategies for addressing misconceptions in electric circuits.

Dr ST Maseko
Director
STMbondvo editing services

<u>**Confidentiality**</u>: *In editing academic documents, I understand that I have access to confidential data, that information contained in documents is confidential and for that, I agree not to divulge, publish, make known to unauthorized persons or to the public the data in documents.*

APPENDIX 14: TURNITIN CERTIFICATE

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