An investigation of challenges experienced by Physical Sciences novice teachers when teaching Electric circuits in Grade 10 science classrooms: A case of Johannesburg North District schools

A research project submitted to the Faculty of Humanities, in fulfilment of the requirement for the degree of Masters in Education

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June 2023

ABSTRACT

The National Senior Certificate (NSC) diagnostic reports over the years have shown that learners perform poorly in electric circuits in the Grade 12 Physical sciences final examinations. This has raised concerns to identify the underlying reasons behind this. The learners' performance is often linked to the teachers' content knowledge and pedagogical knowledge. This study sought to understand the challenges that physical sciences novice teachers experience when teaching electric circuits in Grade 10 as well as the factors that contribute to these challenges. In understanding the challenges experienced by the novice teachers, this study was underpinned by Bhaskar's (1978) theory on Critical Realism as a theoretical framework to reveal the teachers' challenges in relation to their content and pedagogical knowledge. In conjunction to this, the study was guided by Archers' (1995) constructs of the Social Realist Theory. The two theoretical frameworks were used to analyse the data, using stratified levels of reality from critical realism and analytical dualism from the social realist theory as an analytical tool. Employed in this study was the qualitative case study research design. The data was collected through twenty online questionnaires and five individual online semi-structured interviews with physical sciences novice teachers from the schools in the Johannesburg North district. These instruments were used to provide an in-depth account of the challenges experienced by the novice teachers and their contributing factors.

The study found that the novice teachers experienced challenges with the lack of specialized resources such as fully functional laboratories and content related challenges, such as misconceptions, gate-keeping concepts and teacher centred approaches. The findings also revealed that despite being technologically oriented themselves. The findings also revealed that the novice teachers experienced challenges with the use of ICT in their teaching of electric circuits, owing to a variety of reasons related to the context of the school, their pre-service training as well as general beliefs about ICT. The study recommends that teacher training programmes should perhaps look into firstly, teaching the pre-service teachers more on how to improvise, given that most schools lack resources and secondly, the methodology courses need to consider focusing on how to equip the teachers with the correct conceptions of the main concepts of electric circuits in order to minimise the misconception perpetuated by the novice teachers as well as build they confidence in the instruction of electric circuits. The rationale for this study was on the grounds that there is not much physical science education research clearly accounting for the challenges experienced by the novice teachers post the millennial generation and the COVID-19 pandemic. This study provides ground for other researchers to explore the nature of science teaching with this current generation (generation Z). The findings from the research study reveal that the current generation experience challenges beyond content knowledge, such as a short attention span. In light of this finding, this study suggests that future research should be aimed at incorporating the technological aspect of teaching in science topics in order to make the science topics interesting and relevant to the learners.

Keywords: *Novice teacher, Content knowledge, pedagogical knowledge, Information Communication Technology (ICT), Generation Z, Critical realism, Social Realist Theory.*

DECLARATION

I, ***HLAYISANI TRACY NKUNA (1147317)***, hereby declare that this research report is my original work and that it has not been submitted prior for assessment for any other academic qualification at any other university. All the work cited has been referenced accordingly and a complete list of the references has been provided. I acknowledge that the University of the Witwatersrand will take disciplinary action against me if the research shows evidence that suggests that the work submitted is not my original work.

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University of the Witwatersrand, June 2023

Protocol number: 2022ECE023M

ACKNOWLEDGEMENTS

I would like to express my greatest gratitude to my supervisor: Dr Emmanuel Mushayikwa for the professional support, motivations and patience you have given me. I am grateful for the times you kept me going even when I felt like giving up. To my parents, Nkhensani and Gezani Nkuna, thank you for your immeasurable support. To my brothers, Matimu and Nyiko, you have been my sanity throughout this journey. I would also like to thank my academic companion, Kushi Kufa, for your constant check-ups and words of encouragement. Thank you for walking this journey with me. Lastly to my precious daughter, Vunene Nkuna, thank you for being my source of motivation throughout the ups and downs.

ABBREVIATIONS

CAPS – Curriculum and Assessment Policy Statement

COVID-19 – Corona Virus Disease of 2019

DBE – Department of Basic Education (Republic of South Africa)

ICT- Information Communications Technology

JN- Johannesburg North

NSC – National Senior Certificate examination

NQT- Newly Qualified Teacher

Wi-Fi- Wireless Fidelity

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CHAPTER ONE

1.1 Introduction

Teachers play a central role in ensuring that effective teaching takes place in a classroom. Vygotsky (1978) emphasizes the role of the teacher as a facilitator in the development of learners. Piaget (1964) further acknowledges the role of the teacher in the cognitive development of the learners. The primary focus of this study is the novice teacher. Novice teachers are often defined as newly qualified teachers (NQT) (Ahmed et al., 2020; Cain, 2012 and Khan, 2018). Farrell (2012) argues that the novice teacher is not limited to NQT but also includes those that are new to teaching a particular grade or subject regardless of the number of years in the teaching field.

In this case, it is important to take into account that the term 'novice teacher' encompasses a variety of identities, for instance, we have the inexperienced teacher, the off-field teachers, retired teachers that have resumed duties after being out of practice for a long time, teachers that have not taught a particular grade for years and as such may be out of touch with the current pedagogical changes within that grade.

According to Mavhunga & Rollnick (2011), it is important to develop teachers in order to ensure that quality teaching and learning takes place in the classroom. In order to develop teachers, one needs to first understand the challenges that hinder teachers from performing at their full potential. This study focused on understanding the challenges that novice teachers experience when teaching electric circuits in Grade 10, the factors that influence these challenges and how the challenges are resolved.

Having been exposed to different philosophical and theoretical perspectives during my undergraduate and postgraduate years in university, I found Critical realism and the Social realist theory to be the most suitable for my research study. The rationale behind this choice is based on the grounds that the critical realism and social realist theory are guided by a depth ontology. These two constructs acknowledge that there are underlying generative mechanisms that influence the world and how we experience it, furthermore, we experience the world at different levels of reality (Bhaskar, 1978). In this study, this means that in order to understand the challenges experienced by the novice teachers when teacher electric circuits, one needs to understand the factors tangible and non-tangle that influence these challenges, these form part of the causal mechanisms. Additionally to understand the world and how we experience it, one also needs to explore the interactions of three separate dimensions: Culture, Structure and Agency as proposed by Margaret Archer (1995). These three dimensions not only influence the kind of challenges experienced by the novice teachers but also acknowledge how individual teachers react and/or overcome the challenges.

One fundamental aspect in the development of the modern society is Electricity and its uses. Most technological innovations if not all, require electricity to operate and thus the concept of electricity remains one of the largely explored topics in the South African curriculum, hence this study's focus on electric circuits. Beaty (1996); Hekkenberg et al. (2015) and Moodley (2013) argue that, although electricity is a fundamental concept in the curriculum, it is also one of the topics that is conceptually difficult for learners to understand across all school levels (Grades 8- 12). According to Ogegbo et al. (2019), these difficulties arise as a result of the failure to link the concepts learnt with real life circuits as well as from misconceptions. Furthermore, the vague understanding of the basic electric circuits concepts contributes to these challenges. In essence, challenges are linked to both the content knowledge as well as the teachers' pedagogical decision making.

Boakye & Ampiah, (2017) assert that a variety of factors may contribute to the challenges that the novice teachers experience. These challenges may be peculiar to the school and the individual as well. In this line of thought, the teacher's agency becomes one that is imperative to explore. According to Arnold & Clarke (2014), agency refers to an individuals' capacity and will in acting intentionally towards a desired goal. In this instance, although there are a multitude of challenges experienced by the teacher in the classroom, however, it is important to highlight and also appreciate the role that the teachers' agency plays in ensuring that effective learning takes place.

1.2 Background of the study

Over the years, teacher education institutions have seen a rise in the enrollment of students as well as graduates into the education field. For example, over the 5-year period 2012-2017 there was an increase in NQT from 8000 to 23800 (Department of Basic Education, 2018). Boakye & Ampiah, (2017) argue that, the term 'qualified teacher' is misleading because obtaining a degree does not necessarily mean one is adequately prepared for the school environment. Boakye & Ampiah (2017) further argue that the teacher education programs primarily focus on the theoretical aspects of the school environments. Moreover, other school realities that impact the teacher's ability to work are rarely considered, such as the availability of resources and facilities for effective teaching and learning.

Fraser, et al. (2007) posit that many challenges that novice teachers' experience arise in practice. These challenges involve adjusting to the workplace, lack of resources and the lack of confidence in their content knowledge among other things (Swart, 2013). Esau (2017), further highlights that in South Africa, teaching and learning is hindered by a number of factors both educational and non-educational, for instance, teachers are faced with an increased workload, this is including tedious administrative work, assessment tasks, extra mural activities as well as classroom management issues. In my experience, I have witnessed that teachers are overburdened with these activities instead of the actual teaching and learning. The focus is largely on meeting the submission of administrative work rather than effective teaching and learning. This is further supported by a survey conducted by Weston (2014) which found that in South Africa, only about a third of the teachers' time is spent on teaching and learning. This study further reported that teachers spent a significant amount of time on administrative duties.

Another challenge reported by Mathevula & Uwizeyimana (2014) and Esau (2017) is overcrowded classrooms. Esau (2017) argues that the learner and teacher ratio in the South African classrooms is 'unacceptable', arguing that in some schools in the KwaZulu-Natal province classrooms average about 55 learners per class. Esau (2017) further argues that overcrowding hinders teaching and learning because the teacher is unable to give one on one feedback to the learners. Having taught at an urban school and most recently at a rural school in Limpopo, however only briefly, I have noticed that the science classrooms are considerably smaller in urban areas as compared to the rural areas. This leads me to believe that the challenges of overcrowding affect the rural areas more. However, even in the small classes, teachers struggle with giving one on one attention as the time allocated for teaching and learning in some schools is not enough to meet both the syllabi coverage requirement, administrative duties and one on one interactions with the learners.

The challenge of lack of resources affects schools both globally (Fino, 2018; Mathew, 2011; Muyambano, 2019) and locally (Botha & Rens, 2018; Fuzani, 2018). In South African schools, this is mostly seen in the township and rural areas. Esau (2017) states that most schools in these areas lack basic amenities, proper infrastructure and learning resources such as water, decent toilets, electricity, libraries, computers and also laboratories to perform experiments. This makes the teaching of science difficult, especially to the internet and technology driven learners we have in the classroom today.

In addition to the challenges experienced by the novice teachers, is the lack of parental involvement. Most learners from rural and township areas come from poverty-stricken families, with parents that have little or no formal education. This lack of formal education limits parents from being educationally involved in their children's schooling. Rosenberg (2004) states that parents struggle to be involved in school interventions because they do not know how to help. Holsen (2013) and Singh, et al. (2004) further assert that the socio-economic status and parents' educational levels are factors that affect the children's education. These challenges pose a challenge for novice teachers as they struggle to have interactions with the parents with regards to their children's educational challenges.

According to Duse & Duse (2016), teachers experience challenges in the teaching of physical sciences especially teaching electric circuits to the generation Z cohort. The generation Z cohort according to Duse & Duse (2016) is the generation born from the years 1996 to 2010. The generation Z cohort are classified as digital natives. Mckinsey & Company (2018) state that digital natives are the generation of individuals who were born and grew up completely surrounded by digital devices such as computers, smart phones and other technological devices. This generation is characterized by their heavy reliance on technology. Spark & Honey (2015) assert that the generation Z cohort spend about 41% of their time outside school on their computer, phones and other technological devices. Fino (2018) further argues that the generation Z cohort rely heavily on the use of calculators and technology because this group was born into the digital world which continuously offers developed software solutions to everyday problems and as such are mainly intrigued by digital oriented instruction. Trajkovic (2011) asserts that the generation Z learners' constant use of calculators and other technological tools such as computers and phones pose an obstacle for developing conceptual understanding of concepts because the learners focus on the mathematical applications rather than the abstract reasoning of the concepts. Fino (2018) also states that this is because this generation is impatient and driven by immediate gratification.

The generation Z cohort have easy access to information, for instance, when solving scientific questions they can simply get the solutions on the internet as opposed to working out the solutions on their own. In my own experiences, when learners are given a take-home assessment, most learners first search for the solutions on the internet before attempting to solve the questions. In some cases, learners are caught with cell phones during formal assessments because they have now become used to getting answers from the internet as opposed to actually studying, thus there is a lack of interest in the conceptual understanding of concepts taught in the classroom. In this sense, it is important to align teaching and learning with the 4th industrial revolution to cater for the type of learners we have currently.

The easy access to the internet exposes the generation Z cohort to a lot of information from various sources of information such as social media, science fiction, science documentaries, fantasy movies etc. These resources perpetuate some misconceptions as well as alternative conceptions to the scientific concepts, for example, learners believe that current is consumed in electric circuit and that's the reason most digital devices stop working when the battery is 'finished', furthermore, that charge is stored in the battery (Fuzani, 2018; Moodley & Gaigher, 2019). These misconceptions become a challenge for the teacher when teaching electric circuits. In light of this background, this study focused on the novice teachers' when teaching the generation Z cohort electric circuits.

Additionally, teaching in the post COVID-19 pandemic has developed in favour of the Generation Z learners. The COVID-19 pandemic has promoted a dual nature of teaching that involves both contact and online methods of teaching. This means that there has been a rapid inclusion of technology in facilitating teaching and learning (Moloi,2020). The department of basic education has developed websites that have digital study material, such as textbooks, study guides and exam past papers. Furthermore, the department has pre-recorded as well as streamed lessons available for revision purposes, especially for the Grade 12 learners.

Teachers in the classroom also use online platforms such as WhatsApp groups to share learning materials such as videos. There has also been a rise in the teachers using TikTok to make videos teaching learners certain topics. These modes of teaching are new to science education and little research has been done about their use (Duma, 2021). Over the years the department of education has also introduced the use of smartboards to facilitate teaching. One major concern is that the teacher training programmes in the tertiary institutions have not developed much to include these current trends. As such the novice teachers are not adequately equipped with technological knowledge in relation to the teaching of electric circuits and thus they encounter challenges in making the topic relevant to the generation Z learners.

1.3 Rationale

According to Moodley (2013), South African schools do not have enough qualified science teachers. Moodley (2013) further states that only about 40% of science teachers have a degree in science and that a number of teachers lack sufficient subject content knowledge as well as knowledge to pick up misconceptions and the knowledge to find better teaching methods to help learners understand the science concepts. This is a challenge that poses a threat to the quality of teaching and learning in science classrooms. Some other challenges arise from the school environment itself, lack of resources, workplace relations etc. (Boakye & Ampiah, 2017). It is therefore important to identify and understand the challenges faced by novice teachers to find potential solutions that will be beneficial not only to the current teachers but also to future novice teachers when faced with similar challenges.

The CAPS curriculum comes after a number of curriculum reformations in South Africa post the apartheid era, from Curriculum 2005 to the National Senior Certificate (NSC) and recently the Curriculum Assessment Policy Statement (CAPS). The NSC focused on the need for learners to be critical thinkers and problem solvers by shifting from a teacher centered approach to a learner-oriented approach (Gudyanga, 2017). The CAPS document according to Gudyanga (2017) is reorganized in such a way that makes the implementation of the NSC easier.

One of the topics in the CAPS document that has proven to be difficult to teach due to the poor performance across all school levels is Electric circuits (Moodley & Gaigher, 2019). The 2022 diagnostic report for the Grade 12 National Senior Certificate (NSC) examination shows that the learners performed poorly in electric circuits, obtaining a 41% pass percentage as compared to other topics like Newton's laws of motion and Vertical projectile motion where the learners obtained 72% and 61% respectively. Swart (2013) posits that novice teachers tend to rush through or avoid difficult topics at the expense of learner understanding, for example, topics such as electrostatics and electrodynamics, thus resulting in misconceptions that learners carry with to Grade 12. When teachers' rush through topics, it leaves learners with little time to fully grasp and conceptualize the main concepts of the topic.

Many fundamental concepts are taught in Grade 10, for example in electric circuits, concepts such as current, voltage and resistance are taught in Grade 10. These concepts are then reinforced in Grade 11 and then later in Grade 12. When learners lack a strong foundation of these concepts from Grade 10, they tend to struggle with the topic of electric circuits in Grade 12, thus negatively affecting the quality of electric circuits instruction. With deeper insight on the challenges that the novice teachers experience and ways to solve these challenges, novice teachers will be at a better position to effectively teach electric circuits.

1.4 Problem Statement

Challenges encountered in the classroom during instruction may hinder the conceptual understanding of science concepts. Research reveals that novice teachers are most susceptible to experiencing challenges when teaching science due to a number of reasons as mentioned in section 1.2. Muyambano (2019) argues that these challenges contribute to the novice teacher's poor performance as well as lack of confidence in their skills as teachers. The difficulties as experienced by novice teachers negatively impact on the content delivery and as a result the quality of the Physical sciences education.

Although a lot of research has been done on the challenges that novice teachers face in the classroom both globally and locally, there is little research that focuses on the challenges specific to the teaching of electric circuits, more especially when teaching the generation Z cohort. This research study also draws significance of the influence of technology and the internet on the type of learners that occupy the classrooms today with regards to teaching and learning.

The study seeks to understand the exact challenges experienced by physical science novice teachers with respect to electric circuits teaching, factors contributing to these challenges and how the challenges are currently being addressed and how they can be addressed properly. These challenges were identified through semi-structured interviews and a questionnaire with the novice teachers in order to get in-depth information on the teachers' experiences. Understanding the challenges that novice teachers' experience and addressing these challenges may result in an increase in the quality passes as well as an increase in the number of learners enrolling in the Physical sciences classroom.

1.5 Purpose of the study

The main aim was to understand challenges, if at all, experienced by physical science novice teachers within school contexts, specifically, when teaching electric circuits in science classrooms. Secondly, it was to unearth factors that contributed to the experienced challenges by the Physical science novice teachers and to examine ways in which the experienced challenges were addressed, in order to improve teaching and learning of electric circuits.

1.6 Main research question

The aim of this study was to answer the following main research questions:

How do grade 10 novice physical sciences teachers perceive the challenges they encounter while teaching electric circuits to generation Z learners?

1.6.1 Research Questions

This research study was guided by the following sub-questions:

1. What challenges do the Physical science novice teachers say they experience when teaching Electric Circuits to generation Z learners in Grade 10 science classrooms?
2. What factors do the Physical science novice teachers attribute to the challenges experienced during their teaching of electric circuits?
3. How do Physical sciences novice teachers address these challenges?

1.7 Significance of the study

The knowledge obtained from this study may contribute information about the challenges Physical sciences novice teachers face when teaching electric circuits in Grade 10. Furthermore, knowledge from this study could give insight to teacher professional development programs and institutions aimed at developing novice teachers on how to better prepare the novice teachers in order to not perpetuate the challenges being faced by the current novice teachers.

The knowledge gained from this study may shed light on how school environments can adjust in order to respond to the challenges that novice teachers face or to limit the challenges faced by novice teachers altogether. The knowledge gained from this study is not only limited to novice teachers as it could also help experienced teachers experiencing the same challenges. According to Thijs & Van den Akker (2009), it is important to gain information on existing issues and the possibilities to improve them. Therefore, it became important to identify the challenges novice Physical science teachers experienced when teaching electric circuits in order to address them promptly.

1.8 Chapter Summary

This chapter introduced the study, as well as the objectives of the study. The reviewed literature thus far suggests that novice teachers experience numerous challenges when they get into the field. These challenges include adjusting to the workplace setting, lack of resources, lack of confidence in the content knowledge to name a few.

A lot of research has been conducted on novice teachers, however, most research largely focused on interventions rather than on identifying the challenges that made the intervention necessary. It is evident that although novice teachers experienced general similar challenges, however, there are challenges that are specific to the subjects that the novice teachers teach and thus research focusing on novice teachers needs to be tailored to their specific subject and individual needs. The challenges experienced by science novice teachers may potentially be solved by providing sufficient induction and mentoring programs focused on their specific needs. In the next chapter, a detailed review of literature to understand the challenges that Physical science novice teachers experienced when teaching science is provided.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter aimed to review the literature that has been written about the challenges Physical science novice teachers experience when teaching in a science classroom as well as to identify the gaps not explored by the previous researchers. The literature review looked at the difficulties teachers experienced when teaching science, specifically when teaching electric circuits. The central focus of this study was novice teachers and this concept is also explored.

2.2 Who is a novice teacher?

The term novice teacher, according to Boakye & Ampiah, (2017) and Kim & Roth (2011) refers to a teacher with five or less years of teaching experience. In contrast, in the South African context (Barret et al, 2002 and Lewis et al, 2006) define the novice teacher as one with less than three years of teaching experience. However, from both these definitions, there is a general consensus that a novice teacher is one with a limited number of teaching experience years. Lewis et al (2006) argues that defining novice teachers according to the number of teaching experience years is a limited view and that there exists a variety within the term, "novice". Farrell (2012) posits that the term 'novice teacher' extends beyond the number of years in the teaching field, but rather refers to anyone teaching something new for the first time, including veteran teachers.

According to Farrell (2012), a teacher may have many numbers of years in the teaching field but possess just 3 years' experience in teaching a particular grade or subject. In this sense this teacher can be considered a novice in that grade or subject. The COVID-19 pandemic saw teachers teaching subjects outside their qualification scope, as result of adhering to the social distancing protocols, for example, in my school, I was allocated a Mathematical literacy classroom despite not having this as one of my teaching subjects. In this sense I can be considered a novice teacher in Mathematical literacy despite having four years of teaching experience. As such, in this study, the definition of a novice teacher is not only limited to newly qualified teachers but also includes off-field teachers, teachers resuming duties after being retired for a long time and teachers with little experience in the teaching of physical science Grade 10 (Lewis et al, 2006).

A study conducted by Corcoran (1981) found that when teachers first enter a new teaching context, they experience what they term a period of 'transitional shock', where they realise that they have to perform duties same as the experienced teachers. Moreover, the novice teachers struggle to socially integrate within the school environments and are often burdened with the challenging classes (Whitaker, 2001).

Novice teachers need to get support from their colleagues and other support structures (the school districts) through mentoring and inductions as well as engage in self-driven learning through reflections and attending subject matter workshops (Swart, 2013). Swarts (2013) goes on to say that, without guidance, the first years of teaching in a new context can become overwhelming to the novice teachers and this may cause challenges in their teaching. However, it is important to note that every individual is different and thus will have different experiences of the teaching profession. Taking this into consideration, as much as there are differences there also exists similarities with regards to the challenges faced in the classroom. This study intended to draw out these challenges and use them as a scope to enhance the learners' understanding of electric circuits.

2.3 Teacher training vs school realities.

Literature, Fantilli, & McDougall (2009); Georgalak (2013) and Mkandawire et al. (2016), points out that there is a mismatch to how the teachers are trained and to the realities of the teaching profession. Novice teachers struggle to adjust to the workplace setting (Sharplin et al, 2010); furthermore, the difference in environment is amongst some of the reasons that contribute to the 'transitional shock' that novice teacher's experience. Swarts (2013) states that, novice teachers are not always adequately prepared for the school world. Universities primarily focus on the theoretical aspects of the teaching profession and pay little attention to the social dynamics that come with the profession. However, it is imperative to also note that the scope to which the university can prepare individuals socially for the workplace is limited, because universities are not able to recreate environments that will resemble the actual workplace (Allen, 2009).

2.4 Challenges experienced by novice teachers in the physical science classroom.

According to Boakye & Ampiah (2017), there are quite a number of challenges that teachers experience in the physical sciences classroom. He & Cooper (2011) conducted a study to identify the type of challenges novice teachers experienced generally and came up with a list as follows; testing pressures, lack of administrative support, lack of up-to-date resources, lack of parental involvement, restrictions in time allocation as well as the difficulty in balancing their professional responsibilities with their personal lives. One of the biggest challenges documented by Mel nick & meister (2008) was classroom management, citing that the newly qualified teachers are generally not well prepared in handling behaviour problems in the classroom. Similarly, Muyambano (2019) found that the novice teachers also struggle with the lack of interest from the students and generally dealing with different personalities in the classroom.

Boakye & Ampiah (2017) assert that challenges experienced by novice teachers are not only limited to novice teachers and that veteran teachers experience these as well. Furthermore, physical science is seen as a difficult subject and some challenges also lie in finding ways to make the subject interesting for the learners especially with the lack of resources as is the case in most South African schools (Legari, 2004). Teachers also struggle with completing the science syllabus, moreover, some teachers lack confidence in their content knowledge. He & Cooper (2011) propose that some of these challenges can be prevented if the novice teachers receive proper guidance and support from the relevant structures in order to induct them professionally into the teaching context.

This study aimed to identify some of the challenges novice teachers are experiencing when teaching one of the core topics in the CAPS curriculum (grade 10 Electric Circuits) so as to better prepare the novice teachers and consequently improve their instruction of electric circuits. Over the past years, the National Senior Certificate (NSC) diagnostic reports have shown that learners perform poorly in the topics relating to electric circuits. This leads one to believe that learners have a poor understanding of the topic and thus there is a need to explore challenges that teachers experience when teaching this topic. A focus on a specific topic enables the researcher to get an in-depth understanding of the difficulties related with the teaching and learning of that topic. Ndlovu (2017) acknowledges that it is necessary to research on specific topics as challenges experienced may differ from topic to topic.

2.5 Teaching electric circuits

Teachers hold a lot of views of how teaching should be approached in the classroom. Many physical sciences teachers agree that electricity is one of the most conceptually challenging topics in the CAPS curriculum (Hekkenberg et al, 2015), as well as on an international level (Saglam & Millar, 2006). This topic forms one of the important topics worldwide and understanding it may positively contribute to an overall conceptual understanding of science

(Ogegbo et al, 2019). Studies dating as early as Driver & Easley (1973) show that learners carry with them many misconceptions about electric circuits. These also arise from preconceptions originating from different cultures as well as experiences. The topic of electric circuits is taught throughout the CAPS curriculum and thus the poor understanding of pre-existing knowledge is carried with to Grade 12 (Kriek et al, 2011).

A study conducted by Mulhall et al (2001) in Australia found that there were a number of issues relating to the teaching of electricity. Teachers had difficulties with discussing their own conceptual understanding of basic concepts such as voltage and current. Teachers also struggled with defining the term potential difference and their incorrect use of terminology contributed to the misconceptions learners developed. Furthermore, teachers felt it was easier to teach electric circuits using algorithmic methods resulting in conceptual understanding being ignored (Farrell, 2012).

In relation to the South Africa context, Moodley & Gaigher (2019) and Kriek et al (2011) argue that teachers have little awareness on how their teaching contributes to the learners' misconceptions and confusions of words such as current, charge, energy, power as well as potential difference as they use these words interchangeably. Some of the confusion of these words comes from how they are used in everyday experiences, for instance energy and power are mostly interchanged in everyday conversations outside the classroom. Drawing from my experiences, I have also noticed that some learners do not know the meaning of these terms in the scientific context as they have never been exposed to them, for instance the term potential difference.

Fuzani (2018) asserts that some teachers have a poor understanding of the basic concepts of electricity and as such struggle to conceptually teach them. Esau (2017) further posits that another challenge in teaching electric circuits, is that most schools lack resources as the equipment is either old, damaged or non-existent, furthermore, most schools do not have a laboratory to conduct the related experiments especially in the rural and township schools. The lack of resources results in teachers using traditional teaching techniques. In this instance the textbook becomes the main resource during instruction (Fuzani, 2018; Ramnarain & Moosa, 2017).

During my secondary schooling, my physical science teacher relied on videos from the internet to show how the experiments in electric circuits and other topics are conducted to enable us to do the assessment tasks and as such we never got a hands-on experience of handling electric circuits. As such, I was only exposed to practical work when I got to tertiary level. Situations such as these rob learners of getting a holistic experience of the science subject.

Studies in Pedagogical Content Knowledge (PCK) according to Moodley & Gaigher (2019) provide a strong emphasis on the link between learner understanding and how learners are taught. Teachers' perceptions of electric circuits are related to how they teach the topic and thus poor understanding of the content knowledge may be detrimental to the learners' conceptual understanding of the basic concepts.

2.6 Challenges teaching electric circuits

According to Burde & Wilhelm (2019), learners encounter problems with understanding electric circuits as well as analyzing simple circuits due to an excessive focus on concepts such as current and resistance. Burde & Wilhelm (2019) further argue that, when learners analyze electric circuits, they tend to do it through the use of current and view voltage as a "property" of current and not an independent physical quantity, consequently they have difficulties understanding the relationship between current and voltage. Burde & Wilhelm (2019) state that simple circuits are not simple for the learners as learners often have a poor grasp of the concepts of current, resistance and voltage. The learners also struggle to understand the complex processes such as the movement of electrons as these are abstract. Majority of these problems according to Moodley and Gaigher (2019) are caused by the traditional methods employed when teaching electric circuits. Moodley & Gaigher (2019) posit that most of these traditional methods involve a huge focus on the quantitative aspects of electric circuits such as Ohm's law. Moodley & Gaigher (2019) further argue that a number of the teachers, especially in the South African context do not teach science conceptually but rather prefer to focus on algorithmic teaching and thus learners' conceptual understanding of electric circuits remains underdeveloped hence the learners lack a conceptual understanding of the display of the Ohm's law.

According to Burde & Wilhelm (2019), one major concept learners struggle with is voltage, further arguing that not only do learners struggle to understand voltage as potential difference but also the effect of this voltage on the simple circuits. As such, the learners solely focus on understanding electric circuits only via current. Moodley and Gaigher (2019) concur that the focus on current poses a problem because a conceptual understanding of voltage is important in analyzing electric circuits. The constant misguided focus on current robs the learners of conceptual understanding. Burde & Wilhelm (2019) propose that the difficulties in understanding the concept of voltage are also as a result of how the concepts of electric circuits are traditional presented in the textbooks.

In addition Moodley & Gaigher (2019) argue that one of the central problems to teaching electric circuits is misconceptions carried by both the learners and the teachers. Mavhunga & Rollnick (2011) state that misconceptions hinder the understanding of science concepts. Furthermore, even though teachers may be aware of the misconceptions but they are not aware of the origins of the misconceptions and how these impact their teaching. Another concern raised by Burde & Wilhelm (2019) was that teachers and some textbook authors showed a poor understanding of electric circuits as a result, many teachers are not comfortable in discussing their own understanding of key concepts such as current, voltage and resistance. Furthermore, most teachers have an inadequate understanding of potential difference and thus this contributes to the misconceptions and the challenges experienced by the novice teachers.

2.7 Chapter Summary

The literature review above revealed that novice teachers have encountered numerous challenges in the teaching of physical sciences and electric circuits and therefore it becomes important to further identify challenges that current novice teachers experience. This study aimed to understand the challenges that the Grade 10 physical science teachers experienced in teaching electric circuits, especially to the generation Z learners. In the next chapter I discuss, the conceptual underpinnings of this study

CHAPTER 3

THEORETICAL FRAMEWORK

3.1 Introduction

The literature review has highlighted some of the challenges as well as perceptions held by teachers in the teaching of electric circuits. This chapter describes the conceptual underpinnings of the study.

Identifying and addressing the challenges experienced by the physical science novice teachers in the teaching of electric circuits involves looking at the context, content knowledge as well as pedagogical knowledge of the teachers. In looking at the context, this study focused on the availability of teaching and learning resources and infrastructure such as laboratories. The content knowledge aspect considered the concepts that were challenging for the teachers, consequently identifying the content gaps in the novice teachers in relation to electric circuits. Lastly the pedagogical aspect was more concerned with the teachers' knowledge of learner prior knowledge and the teachers' teaching approaches. In all these aspects, this study was also interested in the factors that contribute to the challenges and how the teachers resolved these challenges. The aim of this study was to improve the teaching and learning of electric circuits in Grade 10. Keeping this in mind, this study was underpinned by Roy Bhaskar's' (1978) Critical realism in conjunction with Margaret Archers '(1995), Social realist theory

This chapter begins by discussing the constructs of Critical realism and why it was chosen for this study followed by a discussion on the Social realist theory and its analytical tools used in this study. According to Akabor (2020), these two theories "focus on identifying hidden causal mechanisms, how they work, whether they are active or not, and the conditions under which they become active" (P.8).

3.2 What is Critical realism and why critical realism?

In looking for a framework that would better meet my research study goals, I discovered that positivist and idealist philosophies were unable to assist me in achieving my goal of gaining a deeper understanding of the challenges experienced by novice teachers when teaching electric circuits and what factors influence these challenges. This was on the grounds that the idealists view knowledge as stemming from only human aspects that are forced on the phenomenon whilst on the other hand positivists view the world as a sequence of events that represent the world (Bhaskar, 1978). Hence, the use of these two epistemological and ontological assumptions would have resulted in an explanation of the novice teachers challenges that is solely based on what I as a researcher view. In this case reducing the reality of the challenges to my truth of it (Akabor, 2020). Critical realism gives an alternative in contrast to positivism and idealism in that it isolates the events that takes place and what is experienced from these events (Bhaskar,1978). Therefore, I chose this framework on the grounds that its philosophical underpinnings provided a kind of ontological depth which aligned with my aims for this study.

Brenton & Craib (2001) assert that in critical realism, viewing the world at a surface level is deceptive as there is underlying mechanism at play that influence events in the world. Mingers (2000) further proposes that in most cases we may experience the same phenomenon, however differently at different levels. In this sense Mingers (2000) argues that our views of reality are tentative and subject to change. Bhaskar (1978) posits that it is this tentative nature of reality that dismisses the empiricist and idealistic notions of the world. Critical realism aims to comprehend and make sense of the world beyond the surface level.

Critical realism notions are on the grounds and acknowledgement of an outside world that exists autonomously of our encounters of it (Bhaskar, 1998). The nature of the world as it is and what it resembles is not impacted by our experiences or views of it. Benton & Craib (2001) further extend this idea that the outer world also frequently opposes our intentions to comprehend and transform it according to our perspectives. The ontological notions of critical are based on the idea that the reality is differentiated and stratified. These notions are discussed in detail in the sections that follow.

3.3 Differentiated and stratified reality

Critical realism views reality in layers that are differentiated or stratified. Bhaskar (1978) terms these layers: Empirical, Actual and Real to distinguish between these three layers of reality. Bhaskar (1998) fostered the idea that reality is layered and showed that each layer is emanant from the one preceding it. The stratified nature of reality implies that reality can be seen in multiple aspects, beyond what can be observed or experienced with the limitations of our sense abilities.

Bhaskar's (1978) views on reality enable science to be explanatory, focusing on explaining the "why" and looking for the unknown cause of phenomena of the world which influences our experiences of it. According to Elder-Vass (2008), the empirical level comprises of our perceptions and experiences. These are tangible aspects of the world and are often defined by facts. Given the notions that our knowledge of the world is subject to change this level of reality is thus “unstable” and “fallible. This is because as new knowledge is formed through research, our perspective of the world also changes, for example the perceptions of traditional schooling has changed over the years with the change in generations and influenced by new developments in technology, a classroom can no longer be limited to an actual room with desks and chairs but now also encompasses a virtual setting where learning takes place.

In this study the empirical level refers to the contextual factors that visibly cause challenges for the teaching and learning of electric circuits. This includes the availability of resources and school’s social context. These factors are what is responsible (on the surface level) for the challenges experienced by the novice teachers. Bhaskar (1978) introduced the level of the actual and the real which go deeper beyond the empirical level. The actual emerging from the empirical.

The level of the actual comprises of the events that lead to what is observed in the empirical level. The actual level exits whether it is experienced by the individuals or not (Danermark, 2002). According Bhaskar (1978), events at this level are not always observable like in the empirical. Examples of events in this study include learner prior knowledge and the choice of teaching approaches. The events at this level are as a result of social structures and mechanisms at the level of the real.

The level of the real, also the deepest level of reality refers to the effects on the individual as a result of the experiences of the empirical and actual levels. In this study, the real consist of attitudes towards electric circuits, the effects of the lack of resources, the processes involved in the teaching of electric circuits. The level of the real is divided into three mechanisms although separated into different mechanisms namely cultural, structural and agential (Archer, 1995). The table below represents the summary of the three layers of reality.

Table 1: Bhaskar’s’ stratified reality (adapted from Bhaskar, 1978)

	Domain of the real	Domain of the actual	Domain of empirical
Mechanisms	X		
Events	X	X	
Experiences	X	X	X

In aligning with the ideas of critical realism to guide my study. I have decided to use Margret Archers' (1995) social realist theory, in conjunction with critical realism to understand the novice teachers' challenges. Archer's (1995) social realist theory allows the research to consider a methodology that accounts for the different layers of reality involved in the challenges experienced by the novice teachers. Given the dense knowledge accompanying critical realism, Graton (2015) asserts that one does not necessarily have to apply every aspect of the theory and thus only the facets that suit the purpose of the study can be used. This study focused on Bhaskar's (1978) ideas of a stratified reality, also drawing on Archers' (1995) social realist theory, specifically the analytical dualism aspect. Archer's (1995) work builds upon the notions of critical realism and this has developed an analytical framework that looks at the social interactions between culture, structure and agency.

3.4 Social Realist Theory

The ideas of social theory acknowledge the interplay between structure and agency and the strengths that each of these holds. Archer (1995) termed this, analytical dualism. Analytical dualism argues that social parts of life such as structure, culture and agency can be separated in order to understand social reality, Archer (1995) asserts that social reality is multifaceted and involves three elements. The table below shows summary of the three elements

Table 2: Summary of the three elements of analytical dualism

Element	**Description**
Culture	Encompasses the values, attitudes and beliefs of social life
Structure	Encompassing the material things such as resources, social roles and positions.
Agency	Encompassing human aspects such as "who is doing what and to whom'

These elements although viewed in isolation, however are intertwined and have a direct impact on each other. In this study these elements are viewed within the critical realist perspective, doing this enabled me as the researcher to unearth the underlying factors that resulted in the challenges experienced by the novice teachers. The three mechanisms are discussed in detail in the sections that follow.

3.4.1 Culture

The culture element consists of the beliefs, attitudes and ideas of society. These beliefs influence the events at the level of the actual and the level of the real. This study aims to explore the underlying mechanisms in the cultural element at the level of the real. According to Archer (1995), analysis of the cultural element involves first understanding the mental processes, such as the beliefs and attitudes of the society. These mental processes are largely influenced by those in power. Archer (1995) argues that these influences constrain the actions of the people, however they also do not guarantee the society's conformity to the influences. In essence, Archer (1995) states that the cultural element involves "all things capable of being grasped, deciphered, understood or known by someone" (P.104).

3.4.2 Structure

Archer (1995) asserts that the analysis of the structural level involves identifying the tangible objects, human relations and the powers that these have on the society. The structural element of the society consists of the causal powers that are exercised or unexercised on the people Archer (1995). Furthermore, Archer (1995) proposes that when looking at structure, you can look at it either through the positional level, which involves looking at how society is structured as a result of the distributed resources or the structures of institution, which involves examining the interactions of the relations of different institutions in the society.

3.4.3 Agency

Agency acknowledges that people have influence on the how the society is shaped. According to Archer (1995), agency consist of the purposeful actions of people, meaning the decisions that people make. These decisions can either reproduce the existing structures and cultures or change them. Archer (1995) argues that, although there are constraints from the cultural and structural mechanisms imposed on the society. However, we also need to consider that people are not passive members of the society. People are active participants of the society through engaging in reflexive actions.

3.5 Archers analytical dualism

Archer (1995) proposed an analytical framework that acknowledges the differences between structure and agency and their strengths. This was referred to as analytical dualism. Analytical dualism acknowledges that in society, the social entities of life can be separated into "parts and people". The "parts" aspect involves the structure and culture and the "people" refers to the agency. As such, Archer (1995) asserts that social reality can be understood according to three elements which are culture, structure and agency. In elaborating the three elements, Archer (1995) argues that they are not separable in real life and are in fact intertwined. However, for the purposes of analysis, Archer encourages that the three elements be viewed separately as this provides ground for a deeper understanding of their individual societal influences. In this study, these three elements are explored via critical realism. Doing so enabled me to gain an in-depth understanding of the challenges experienced by the novice teachers and the factors that contribute to these challenges.

3.6 Analytical framework

The notions of critical realism and social realist theory discussed above enable me to take into considerations the challenges and their causal factors experienced by the novice teachers when teaching electric circuits. The social realist theory was used to unearth the underlying meanings and impact of these challenges and how the teachers resolve the challenges. The table below shows the analytical framework used in this study

Table 3: Analytical framework adapted from Archers (1995) social realist theory

<table>
<tr><th colspan="4">Challenges experienced by novice teachers when teaching electric circuit</th></tr>
<tr><td>Empirical</td><td colspan="3">Observable challenges experienced by teachers as a result of tangible factors</td></tr>
<tr><td>Actual</td><td colspan="3">Events happening at the school that lead to the empirical level regardless whether the teachers experience these events or not</td></tr>
<tr><td rowspan="2">Real</td><td>Cultural mechanisms</td><td>Structural mechanisms</td><td>Agential mechanisms</td></tr>
<tr><td>Looking at the beliefs, ideas and attitudes influencing the challenges experienced by the teachers</td><td>Looking at the pedagogical methods and school process that led to the challenges experienced by the teachers</td><td>Looking at how the teachers overcome or react to the challenges they experience</td></tr>
</table>

The table above shows how the critical realism concepts of a stratified reality and Archers' (1995) concepts of analytical dualism have enabled me to analyze the different levels that the challenges experienced by the novice teachers when teacher electric circuits manifest themselves in the schools.

3.7 Chapter Summary

This study used the Critical realism constructs as proposed by Bhaskar (1978) and Archers analytical dualism (1995) as an analytical framework to understand the challenges experienced by novice teachers when teaching electric circuits, as well as the challenges they encounter in their contexts. The chapter briefly outlined the two theoretical constructs, which were used as an analytical tool to make sense of the data that was collected. In the next chapter, the research design and methodology guiding this study is described

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

The aim of this chapter was to provide an overview of the processes used in this study that were aimed at meeting the purpose of the study. This includes aspects such as the research paradigm, research method, data collection procedure, data analysis tools as well as rigor. Ethical considerations are also discussed in this chapter.

4.2 Research paradigm

The Critical Realist paradigm served as an organising principle in which the challenges experienced by the Grade 10 physical science teachers were explored. According to Bhaskar (2008), Critical realism has a layered ontology and is often termed the 'under labourer'. It is this layered ontology that enables the researcher to interrogate the educational practices, with the main aim of understanding both the nature of the practices and how these practices evolve over time. Bhaskar (2008) asserts that in order for one to understand and in turn effect change in the social world, one needs to have an understanding of the structures that cause reactions in the social world. In this sense, if one is to understand the challenges faced by the novice teachers, it also becomes crucial to understand the factors that result in these challenges. Drawing on this aspect of critical realism, the researcher is able to go deeper in to the layers of meaning that go beyond the surface of the challenges experienced by the physical sciences novice teachers. This study was concerned with the challenges that stemmed from the novice teachers' interactions with content knowledge and pedagogical knowledge in relation to teaching electric circuits. According to Clarence (2013), when analysing and making sense of our experiences in the social world, we need to look into the deeper mechanisms that are actualised during these experiences. As such Critical realism provides a framework that allows the analysis of these deep mechanisms that result in the challenges experienced by the novice teachers. Critical realism in conjunction with the social realist theory (discussed in chapter 3) provided the conceptual tools that enabled the researcher to analyse the challenges experienced by the novice teachers.

4.3 Research approach

McMillan (2012) sates that there are three types of research approaches, namely: qualitative, quantitative and mixed methods which involve the combination of the first two approaches. According to Cresswell (2012) & McMillan (2012), the qualitative approach involves analysing data through qualitative means such as, organising the data into recurring themes and providing detailed descriptions of the data. In this sense, qualitative methods are concerned with in-depth understanding of the phenomena being studied (Cresswell, 2012). On the other hand, the quantitative approach uses statistical means to analyse the data. In essence, it is numerical in nature. In this study, qualitative methods were employed in analysing the data. This is because the study did not concern itself in the measurement of any variable but rather was aimed at understanding the challenges experienced by the novice teacher (Duma, 2020). Given that the study aimed to "identify" and "understand" the challenges experienced by the novice teachers, qualitative methods seemed more suitable for this study, as it allowed the research to employ in-depth analysis of the data collected. Furthermore, this method allowed for an interpretive perspective of the overall study.

4.4 Case Study research design

Every educational research consists of a research design, which essentially provides a plan as to how the research study will be conducted. Babbie and Mouton (2007) argue that there are three types of qualitative research designs, these being: life histories, ethnography and lastly case studies. The life histories design concerns itself with the development of life of one or multiple individuals, meanwhile ethnography involves looking at larger units of analysis such as communities, populations, cultural groups etc. As such, these two research designs were not suitable for this study. This research study used the case study research design. Case studies, according to Cohen et al (2018) are concerned with a specific group or setting, such as a specific context or institution, moreover, they are clearly defined by boundaries. In this study, the focus was on Grade 10 novice teachers in the Johannesburg North district schools.

Linking with the qualitative approaches, case studies are descriptive in nature, therefore allowing for in-depth analysis of the phenomena being studied. Babbie & Mouton (2010), assert that cases studies enable the researcher to make causal links within the data collected, in relation to this study, this involved identifying the challenges experienced by the novice teachers as a result of contextual and content related factors. In this regard case studies can be viewed as an empirical inquiry concerned with investigating the phenomena in a specific social situation (Yin, 2013).

In addition, this study can be considered a collective cases study. According to Njie & Asimiran (2014) a collective cases study involves a number of cases that are investigated in conjunction with the aim of understanding a particular phenomenon. In this study the participants were studied individually and the data consolidated collectively given that they were from the same research site, The Johannesburg North district. This collective study included 20 Grade 10 physical sciences teachers, each teaching in different schools located in the Johannesburg North District.

4.5 Research data collection tools

Data collection in this study includes 20 teacher questionnaires to survey the teachers on their experiences of teaching novice teachers as well as semi-structured individual interviews with five teachers. The two data collection tools were used to increase validity of the data (Macmillan & Schumacher,2010).

Table 4: The number of tools used in this study

Participant	Data collection tool	Number of responses
Teacher	Questionnaire	20
Teacher	Semi-structured interview	5

4.5.1 Questionnaire

Huysen (1994) asserts that questionnaires are used when the researcher seeks to obtain and understand the opinions, beliefs, attitudes as well as experiences of the participants. Rugg (2007), posits that a questionnaire consists of a list of comprehensive questions prepared by the researcher prior to the commencement of the research study with the aim of meeting the research purposes. In this study, the questionnaire was chosen because it is easy to administer as well as complete, which makes it suitable for gathering information from a somewhat large number of participants. This study gathered information from 20 respondents. In developing the questionnaire, the researcher consulted relevant literature with the aim of gaining knowledge of how research questionnaires are designed. Furthermore, the drafted questions were shared with my supervisor in order to modify them in accordance with the research questions. The questionnaire consisted of two sections. Section one focused on the participants demography, teacher profile, school context and the teachers' school experiences. Section 2 was concerned with the teachers' conceptual experiences (content knowledge & pedagogical reasoning).

4.5.2 Developing the teacher questionnaire

The questionnaire consists of three sections. Section one focused on the demographics of the participants such as the gender, age, qualification type and the number of teaching experience. The second section consisted of the contexts of the school, this included the location and the type of resources available. The third section involved questions regarding the teachers experiences with the content knowledge, teaching methods, problems with calculations. This section consists of attitudes as well as beliefs regarding the teaching of electric circuits. The questions consisted of both positively and negatively worded statements, in order to increase validity. These statements took the form of a five-point Likert-scale to guide the preference of the participants. The preferences ranged from strongly agree to strongly disagree (see appendix 2). In the last section the questions were based on the actual content knowledge and misconceptions teachers may have about electric circuits. This section also included an open-ended question, which was based on an analogy (the water analogy) and how the teachers would explain this analogy to avoid misconceptions about charge. This open-ended question intended to understand teachers' knowledge about charge and how they explained it to the learners.

4.5.3 Limitations of the questionnaire

According to McLeod (2014) questionnaires may have limitations such as, participants not being truthful when responding to the questions. Another limitation is that, it is difficult getting a good number of responses as participants are reluctant to spend a few minutes of their time on questionnaires. McLeod (2014) also argues that the researcher needs to be mindful of the language used when developing the questionnaire, the language should match the participants social backgrounds and educational level. One major limitation of using a questionnaire according to MacMillan & Schumacher (2010), is that questionnaires normally consist of closed-ended questions and thus limits the researcher's interpretations of the participants perspective. In light of this limitation, the semi-structured interviews were also conducted in order to get more information of the novice teachers' experiences when teaching electric circuits.

4.5.4 Semi-structured interviews

Cresswell (2011) posits that there are three different types of interviews: structured, semi-structure and unstructured. Each of these interviews have their own strengths depending on the nature of the research. Structured interviews, consist of pre-prepared questions, for example, questionnaires, often involving pre-determined choices. In contrast the semi-structured interviews, are characterized by open ended questions that are guided by a specific intention and are somewhat objective in nature. Furthermore, semi-structured interviews allow the researcher to probe the participants in order to elaborate on certain aspects. The unstructured interviews are largely open-ended and subjective in nature. The semi-structured interviews were chosen to be more suitable for this study. In this study, online interviews were conducted individually with five different novice teachers from the JN district schools, with the aim of identifying the challenges they experienced when teaching electric circuits.

The semi-structured interviews also enabled the researcher to probe the participant in order to understand their reason behind some of their pedagogical decision making, such as the teaching approaches they used when teaching electric circuits. These interviews were audio recorded and later transcribe verbatim, firstly to get thick descriptions of the data and secondly to allow the researcher to repeatedly analyses the data outside the interview setting so as to ensure that important data is not overlooked. Although the online semi-structured interviews enabled the researcher to gather the necessary data and gain insight to the challenges experienced by the novice teacher. However, face-to face interviews would have been preferred to illicit information from nonverbal, behaviour and gesture responses (Zulu, 2018). The interviews with the participants ranged from 25-30 minutes to give the teachers enough time to express their experiences.

4.5.5 Developing the semi-structured interviews

The semi-structured interviews were guided by an interview schedule (see appendix 1). The schedule consisted of 16 questions addressing all the three research questions, which were: the challenges experienced with regards to content knowledge, teaching approaches, factors that contribute to these challenges and how the teachers resolved the challenges. These questions were used as a guide in order to gain perspective of the teachers' experiences. The questions also allowed me to probe the participants further depending on how the participants responded.

4.5.6 Limitations of the semi-structured interviews

Although the online semi-structured interviews enabled the researcher to gather the necessary data and gain insight to the challenges experienced by the novice teacher. However, face-to face interviews would have been preferred to illicit information from nonverbal, behaviour and gesture responses (Zulu, 2018). Furthermore, Macmillan & Schumacher (2010) argue that semi structured interviews are time consuming and also involve interviewer bias that the researcher needs to be mindful of. In reducing the interviewer bias the interviews were audio recorded to enable thorough account of the participants perceptions about their experiences in teaching electric circuits.

4.6 Research sampling

Cohen et al (2007) asserts that the quality of a research study lies both in the selection of appropriate researcher methodology and the sample strategy used. In essence, the researcher sampling strategy needs to align to the purpose of the study. Given that this research study focused on the challenges experienced by the physical sciences teachers in the Johannesburg North district, the participants of the study were from high schools locate in the Johannesburg North. Being a novice teacher myself, gathering data from the participants was easy to do as most of the participants were my former school mates. As such, the JN district was chosen for its familiarity to the researcher, as this is where I received most of my pre-service training. Moll et al (1992) asserts that in qualitative study the researcher tends to collect data in settings where they would normally spend their time. Moreover, it was easy to understand the challenges experienced by the novice teachers as the context is one that is familiar to the researcher.

According to McMillan & Schumacher (2010), in qualitative research studies, participants are selected purposively. The purposive selection allows the researcher to consciously choose who participates in the research and when. This study used criterion sampling where the participants were selected based on the specific characteristics. The characteristics included that the participants had to be grade 10 teachers, teaching physical science with less than five years of experience teaching Grade 10 electric circuits.

This study involved 20 teachers that teach grade 10 physical sciences from the Johannesburg North district schools. All 20 teachers responded to the online questionnaire. Within these 20 teachers, 5 teachers were selected for the semi-structured interviews to get an in-depth account of the challenges experienced by novice teachers in the teaching of electric circuits. The participants of this study all had less than five years teaching experience in teaching electric circuits. This was done taking into consideration that the research study focused only on novice teachers.

4.7 Rigor: Validity and Reliability

According to Gunawan et al (2015), trustworthiness is an important aspect in a research study as it improves the quality of the research study. Athanasou et al. (2012) argues that increasing the sources of validation, improves the validity of the research study. Sources of validation, according to Cresswell et al (2015) is termed as triangulation and consists of the use of a variety of information sources. In this study data was collected through interviews and an online questionnaire. The findings from these sources were then made accessible to the participants to ensure that the data was accurately interpreted. Furthermore, assistance was sought from my supervisor to help validate the appropriateness of my research design and methodology in relation to the research topic as well as assess the analysis of the data.

Lincoln & Guba (1985) proposes that in ensuring validity and reliability in the research study, the researcher needs to consider the following: credibility, transferability, dependability and confirmability. In making this study credible, accurate presentation and descriptions of the study's findings as well as methodology used to generate these findings was provided, to understand the issues concerning the study. To further ensure credibility, the interviews were audio recorded to ensure that transcripts were more accurate (Betram & Christiansen, 2014).

Lincoln & Guba (1985) refer to the ability of the research findings to be transferred to other similar contexts as transferability. In ensuring transferability, this study provided detailed descriptions of the context, research methods and analysis frameworks, for other researchers to consider when transferring findings from this study to other contexts.

According to Anney (2014) dependability involves the findings being reviewed by the participants to ensure that the interpretations of the data was accurate. In this study, the participants were provided access to the findings so as to confirm the researchers' interpretations of the data. Lastly, confirmability aims to avoid bias in the research study. Confirmability in this study was ensured by comparing the data from the interviews against the data from the questionnaire. Moreover, an audit trail was provided for anyone interested to verify the findings.

4.8 Data analysis

4.8.1 Organising data from the questionnaire

Data was collected through means of questionnaires and semi-structured interviews. The questionnaire was conducted through an online platform that automatically generated the data. The data from section A (appendix 2) of the questionnaire was organised into tables showing the number of participants and the degree to which they agreed or disagreed with the statements given. Below is an example of how the data from the questionnaire responses were organised.

Questions	Strongly agree	Agree	undecided	Disagree	Strongly disagree
I do not have the resources to conduct investigations when teaching electric circuits	8	6	2	2	3
I have adequate resources for teaching electric circuits such as textbooks, electric circuits and other teaching aids	2	5	1	6	6
There are other alternatives I use when I run out of resources	3	14	2	0	1
The problem of resources affects my teaching of electric circuits	6	11	0	2	1

Figure 1: Image showing the questionnaire response presentation

The above table enabled the researcher to be able to compare the findings from the questionnaire with those from the interviews to draw out patterns for analysis. Furthermore, the data from section B of the questionnaire (appendix 3) was organised into pie charts. Below shows an example of how the responses from the conceptual understanding sections was organised

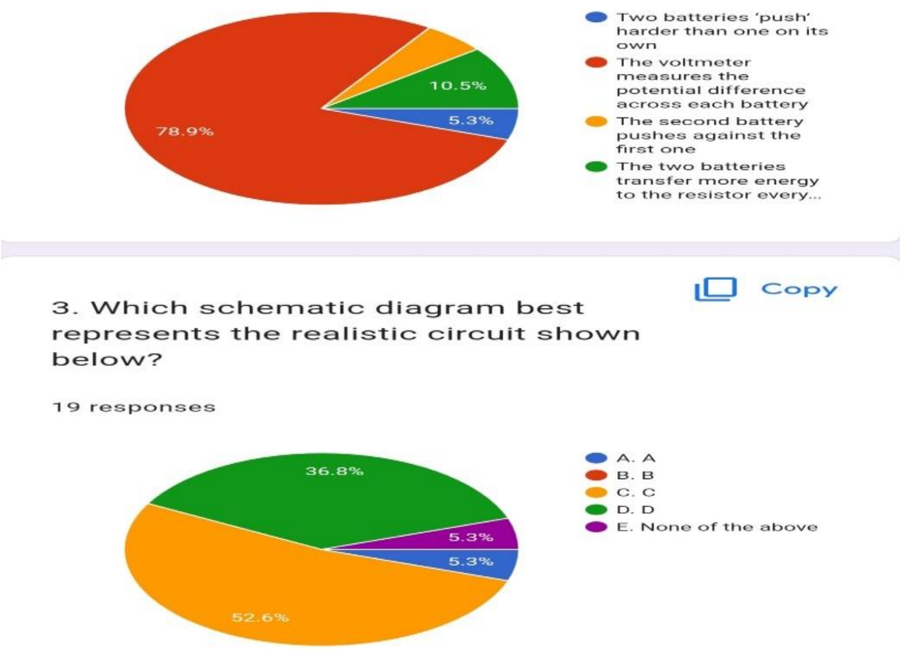


Figure 2: showing the conceptual understanding response representation

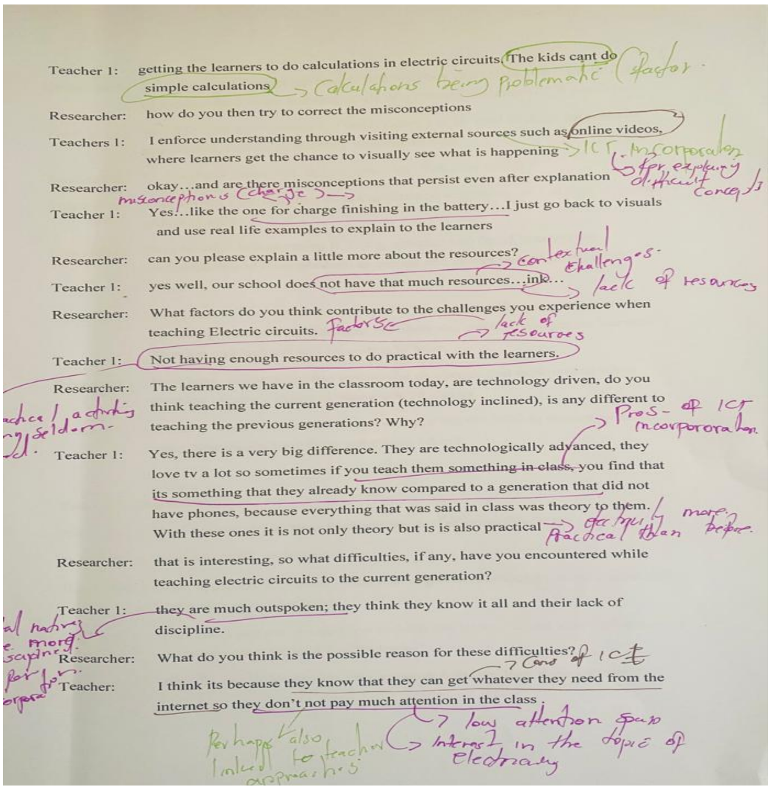
This organisation made it easier for the researcher to interpret the data and make links with findings from the interview responses. Data analysis from the both the interviews and questionnaire was guided by Bhaskar's' (1978) Critical realism and Archer's (1995) social realist theory.

4.8.2 Organising data from the semi-structured interviews

The data analysis process of the semi-structured interviews, firstly involved listening to the interview audio recordings multiple times in order to transcribe them verbatim. Matheson (2017) refers to this transcribing method as "listen and repeat". The transcripts were then coded categories according to recurring similarities. These similarities were then collapsed into emerging themes to enable a thematic analysis. Thematic analysis was used to understand all 5 interviews.

4.8.3 Thematic analysis

According to Caufield (2020), thematic analysis is commonly used in analysing qualitative data. This analysis enabled the researcher to interrogate the teacher responses with the aim of addressing the sub-research questions. Akabor (2020) asserts that qualitative analysis takes place in three different phases, the generative phase, which involves a thorough look of the data word by word, comparing similarities and differences arising from the data. In this study this was done through listening to the audio recording and going over the transcripts multiple times, highlighting the key points and making notes emerging patterns (see image below)



Teacher 1: getting the learners to do calculations in electric circuits. The kids cant do simple calculations → Calculations being problematic (factor.

Researcher: how do you then try to correct the misconceptions

Teachers 1: I enforce understanding through visiting external sources such as online videos, where learners get the chance to visually see what is happening → ICT incorporation → for explaining difficult concepts

Researcher: okay…and are there misconceptions that persist even after explanation

misconceptions (charge) →

Teacher 1: Yes!..like the one for charge finishing in the battery…I just go back to visuals and use real life examples to explain to the learners

Researcher: can you please explain a little more about the resources? → Contextual challenges.

Teacher 1: yes well, our school does not have that much resources…ink… → lack of resources

Researcher: What factors do you think contribute to the challenges you experience when teaching Electric circuits. factors → lack of resources

Teacher 1: Not having enough resources to do practical with the learners.

Researcher: The learners we have in the classroom today, are technology driven, do you think teaching the current generation (technology inclined), is any different to teaching the previous generations? Why? → Pros - of ICT incorporation.

Teacher 1: Yes, there is a very big difference. They are technologically advanced, they love tv a lot so sometimes if you teach them ~~something in class,~~ you find that its something that they already know compared to a generation that did not have phones, because everything that was said in class was theory to them. With these ones it is not only theory but is is also practical → Practical than before.

Researcher: that is interesting, so what difficulties, if any, have you encountered while teaching electric circuits to the current generation?

Teacher 1: they are much outspoken; they think they know it all and their lack of discipline.

Researcher: What do you think is the possible reason for these difficulties? → Cons of ICT

Teacher: I think its because they know that they can get whatever they need from the internet so they don't not pay much attention in the class. → low attention span → Interest in the topic of Electricity

Perhaps also linked to teacher approaches

Figure 3: Image showing an interview transcript and categorisation of data

The second phase is the interpretive phase. The phase involves organising the codes generated in the generative phase into their respective themes. In this phase there is a shift from the highlighted coded notes to now developing themes in which to bases your research analysis in alignment to the research questions.

Table 5: The themes identified from data analysis

Five themes with their related categories from the analysis process				
Contextual challenges	**Conceptual challenges**	**Teaching approaches**	**Lack of interest**	**ICT incorporation**
• Availability of teaching material • Functional basic infrastructure	• Key concepts of electricity • Teachers content gaps • Difficulties with representations	• Direct instruction • Lack of practical activities	• Learners easily bored • Low attention span • Choice of teaching	• Use of online videos • Distraction for learners • Teacher beliefs about ICT

	• Lack of mathematical skills • Learner prior knowledge		approaches	• Lack of technological knowledge

The third and last phase is the theorising phase. This phase consisted of expanding the themes into theoretical explanations. In this phase the social realist theory came into play to enable me to link the data with the research questions. In order to make sense of the themes I used the analytical framework generated from critical realism notions, where I used the knowledge of the empirical and the actual to explore the knowledge that gave rise to the level of the real. I have also drawn on Archer's (1995) analytical dualism to comprehend the underlying mechanisms that influenced the challenges experienced by the novice teachers. Archers' (1995) analytical tool consisting of the three elements: culture, structure and agency allowed me to gain insight to the research problem.

I used the cultural mechanism to refer to the attitudes, believes that the novice teachers have towards teaching electric circuits and its challenges, the structural mechanisms referred to the lack of teaching and learning resources that affected the teachers pedagogical decision making and the agency mechanisms consisted of the ways in which the novice teachers reacted to the challenges which resulted in either an improvement in the teaching experience or the teachers reproducing the same challenges in their instruction. Table 6 below displays the third phase of analysis.

Table 6: The analytical tool used to analyse the data. (adapted from Archer (1995)

Challenges experienced by novice teachers when teaching electric circuit			
Empirical	Observable challenges experienced by teachers as a result of tangible factors		
Actual	Events happening at the school that lead to the empirical level regardless whether the teachers experience these events or not		
Real	**Cultural mechanisms**	**Structural mechanisms**	**Agential mechanisms**
	Looking at the beliefs, ideas and attitudes influencing the challenges	Looking at the pedagogical methods and school process that led to the	Looking at how the teachers overcome or react to the challenges they experience

	experienced by the teachers	challenges experienced by the teachers	

4.9 Ethical Consideration

Ethical considerations are important in a qualitative study as the researcher often engages in face-to-face interactions with their participants. Furthermore, ethical considerations enhance the quality and trustworthiness of the study (Colnerud, 2013). In this study, I first started by submitting an application for ethical clearance at the University of the Witwatersrand ethics committee. After obtaining the ethical clearance, the chosen participants were given participation consent forms, furthermore, the data procedures as well as expectations were explained fully. In this study confidentiality and anonymity were important in maintaining the dignity of the participants and thus was maintained throughout the study. This was done by the use of pseudonyms.

Given that the researcher was the only one involved in the analysis of the data, in order to avoid researcher bias, I was wary to not allow my own bias as a novice teacher to influence the findings of this research study. At all times a conscious effort was employed to maintain the perceptions of the participants by using inductive analysis methods and looking at the data and literature review through an iterative process. In addition to this, I worked closely with my supervisors to ensure a correct interpretation of the data as they acted as external auditors, giving constructive feedback and meaningful contributions to the overall research study on a regular basis.

4.10 Chapter summary

The research methods employed in this study are guided by the critical realism paradigm. The research method I found to be suitable for this study is the qualitative case study method. The data was collected using semi-structured interviews and an online questionnaire distributed to 20 novice teachers. Five novice physical sciences teachers from the Johannesburg North district were the participants for this study for the semi-structured interviews.

CHAPTER 5

PRESENTATION OF FINDINGS AND DISCUSIONS

5.1 Introduction

The reviewed literature suggests that novice teachers face challenges when teaching physical sciences. It is important to further explore these challenges, in order to improve physical science instruction in the classrooms. As such, in this chapter I present and analyse the teachers' interview and questionnaire responses on the challenges experienced by Grade 10 physical sciences teachers when teaching electric circuits. The data is analysed against the theoretical framework discussed in chapter 3. In understanding these challenges, the study was guided by the following research questions:

1. What challenges do the Physical science novice teachers say they experience when teaching Electric Circuits to the generation Z learners in Grade 10 science classrooms?
2. What factors do the Physical science novice teachers attribute to the challenges experienced during their teaching of electric circuits?
3. How do Physical sciences novice teachers address these challenges?

The findings discussed in this chapter were generated from the data collected through 5 participant semi-structured interviews as well as responses from 20 participants from the teacher questionnaire. Responses from both the questionnaire and semi-structures interviews were analysed using thematic analysis processes. The thematic analysis process is explained in full in chapter 4.

In analysing the data collected, I first generated codes, aligning them to the relevant research questions. These codes were then grouped into certain categories and later into themes. See table 7 below.

Table 7: The themes identified from data analysis

Five themes with their related categories from the analysis process				
Contextual challenges	**Conceptual challenges**	**Teaching approaches**	**Lack of interest**	**ICT incorporation**
• Availability of	• Key concepts of electricity	• Direct instruction	• Learners easily bored	• Use of online videos

teaching material • Functional basic infrastructure	• Teachers content gaps • Difficulties with representations • Lack of mathematic skills • Learner prior knowledge	• Lack of practical activities	• Low attention span • Choice of teaching approaches	• Distraction for learners • Teacher beliefs about ICT • Lack of technological knowledge

Caufield (2020) asserts that when doing a thematic analysis, it is important for the researcher to go back and forth between the identified categories and the data multiple times in order to capture the participants perspectives. When I was done coding the data, I grouped the codes according to similar recurring patterns. Through this process five themes emerged:

1. Contextual challenges
2. Concept challenges
3. Teaching approaches
4. Motivation
5. ICT incorporation

The findings in this section are guided by the themes identified and also according to the research questions.

5.2 Findings on the Challenges experienced by novice teachers when teaching electric circuits

5.2.1 Contextual challenges experienced by the Grade 10 Physical novice teachers

This theme focuses on the contextual factors that influence the teachers teaching of electric circuits. Emerging from the questionnaire and interview responses were the factors relating to the availability or lack thereof of resources as well the basic facilities for science teaching such as fully equipped laboratories. Legari (2004) asserts that without such facilities the teaching of science remains at an abstract or theoretical level. Therefore, the lack of teaching material and facilities is a concerning factor for the teaching of electric circuits.

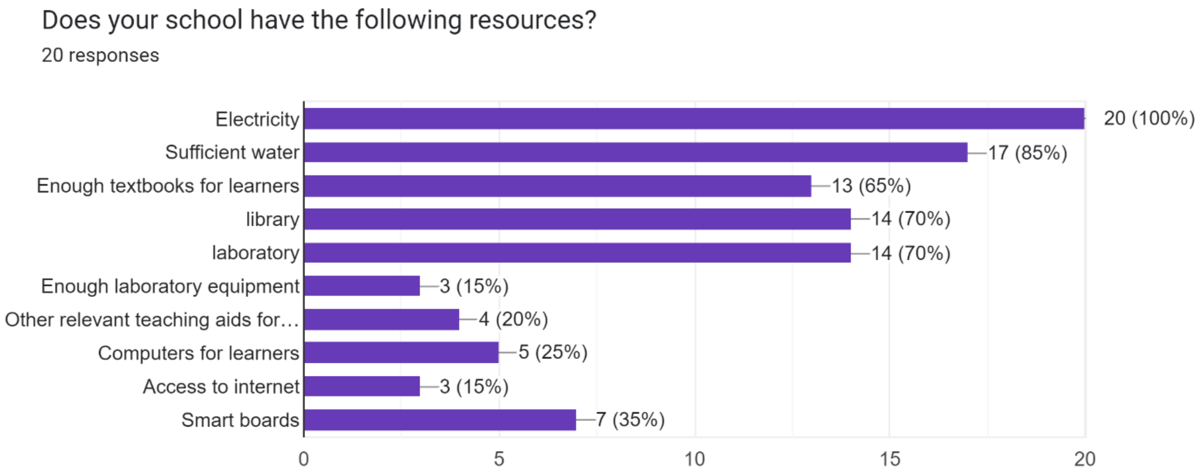


Figure 4: Teachers' responses on the availability of resources

The data from the questionnaire responses as shown by Figure 4 above, indicates that a significant number of the schools have adequate resources and facilities, such as electricity, water, Library room and laboratory centres as well as sufficient textbooks for basic instruction. However, the data also shows that although some of these schools have these basic facilities, but they are not properly furnished with the necessary equipment to optimise their use for the teaching of electric circuits, for example, figure 6 shows that 70% of the schools have a laboratory however, only 15% of the teachers stated that their laboratories had enough laboratory equipment. Furthermore, from the interview responses the teachers stated that these facilities end up being used as storage rooms and classrooms, as stated by Teacher 4 "*we do have a lab but it is used as a storage room".* Additionally, the teachers indicated that they also lacked other teaching aids, where only 20% indicated that they had access to other teaching aids such as charts, interactive worksheets and quizzes. The data also shows that most of the schools did not have computers and with those that had computers, only 15% stated that they had access to internet (Wi-Fi), therefore implying that the use of ICT teaching methods in these schools was little to non-existent. According to Njoko (2018) the use of ICT teaching methods is interactive and encourages learner engagement in the lessons. In this line of thought, ICT could potentially assist learners in the understanding of electric circuits.

The lack of teaching equipment in the laboratories has implications on the teachers' pedagogical approaches as it prevents the use of practical activities in the teaching of electric circuits. The questionnaire responses showed that 14 out of 20 teachers (table 8) did not have adequate resources to do practical tasks. The seldom use of practical activities links with the teachers interview responses when asked about their teaching approaches, where the teachers indicated a dominant use of teacher centred approaches in their teaching of electric circuits. Concurring with this finding, 17 out of 20 teachers (table 8) agreed that the challenges of resources affected their teaching of electric circuits.

Table 8: Shows the teacher's responses in relation to availability of resources

Questions	Strongly agree	Agree	undecided	Disagree	Strongly disagree
I do not have the resources to conduct investigations when teaching electric circuits	8	6	2	2	3
I have adequate resources for teaching electric circuits such as textbooks, electric circuits and other teaching aids	2	5	1	6	6
There are other alternatives I use when I run out of resources	3	14	2	0	1
The problem of resources affects my teaching of electric circuits	6	11	0	2	1

When asked about the lack of equipment in the schools' facilities, the teachers pointed towards the Department of Basic Education's poor service delivery, as well as the resources being stolen by both the learners and members of the community, with Teacher 2 stating that:

> "*Equipment such as computers and smart boards are always stolen during the school holidays, so now we no longer have computers in the school".*

In my own experiences, as observed from my high school and place of work, I agree that a lot of resources are stolen in the schools and once stolen some of the resources are hardly replaced, as such influencing the quality of science teaching in the school. Findings from the questionnaire indicated that 17 out of 20 (table 8) teachers used alternative resources when they run out of basic resource. However, these alternative resources were not specified. The use of alternative resources speaks to the teachers' agency and highlights the importance of improvisation, as other practical activities can be done with improvisation of equipment or learners bringing some materials from home such as batteries, cardboard, paper clips, bulbs and simple conducting wires. These materials can be used to assemble simple circuits such as the example shown below in figure 5.

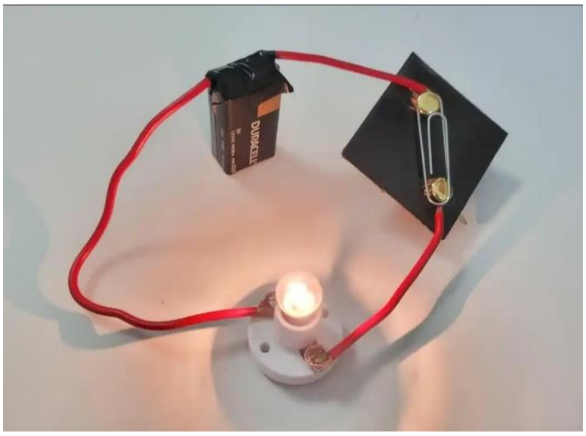
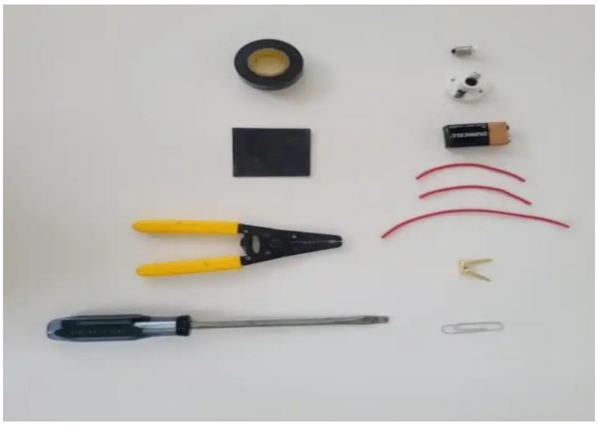



Figure 5: Images showing a simple circuit using accessible materials (adapted from www. Instructables.com)

It is important to highlight that although the data shows that most schools have enough textbooks, it is also evident that there are some schools that experience challenges with textbooks. According to Section 6 of the South African Schools Act 1996, every learner should have the relevant textbooks for the teaching and learning process. The shortage of textbooks in these schools is an obstacle for teaching and learning of electric circuits. The shortage of textbooks in the schools was attributed to a number of factors, were Teacher 3 stated that:

> "*sometimes when you put in the order for textbooks, it arrives towards the end of the year and sometimes the children sell the books outsid*e"

while Teacher 2 stated that:

> "*most of the textbooks we have are damaged, because the kids do not handle them properly, so every year we have books missing pages*"

In this instance it is also important to acknowledge that the schools also have a responsibility in ensuring that the textbooks are well kept by establishing a fully functional LTSM (Learning and Teaching Support Material) committee. The LTSM committee is tasked with ensuring the effective management, utilisation and maintenance of valuable teaching resources.

The issue of textbooks is important, as some of the teachers, although not many, in the questionnaire responses indicated that they relied on textbooks in most of the lessons as shown by table 8 above. In the interview responses, Teacher 2 commented that:

> *"I only use the activities from the textbooks because our school has no ink and photocopying papers to make copies of other resources".*

Teacher 3 also stated that they relied on the textbooks to teach learners about practical work in electric circuits given that their school lacks resources, as stated below:

> *I would like to do investigations with the learners but our school has no equipment, so I just go through the investigation in the textbook with the learners".*

The shortage of textbooks in some schools then becomes a barrier for the teaching and learning of electric circuits.

5.2.2 Conceptual challenges experienced by the novice teachers.

The findings from the study indicated that there were concepts in electric circuits in which the teachers' experienced challenges in teaching, such as current, charge, potential difference, resistance and parallel and series mixed circuits. According to the findings, these challenges stemmed from the lack of adequate content knowledge from the teachers, misconceptions from both teachers and learners, learners' everyday experiences of electricity, the lack of mathematical skills and lastly the teachers' pedagogical approaches. The questions that the participants answered in the questionnaire with the aim of determining the content challenges are presented below (Table 9), along with the findings obtained as a result of the analysis.

Table 9: Shows the teachers' responses to the content related questions

Questions	Strongly agree	Agree	undecided	Disagree	Strongly disagree
My teaching experience in university/ college adequately prepared me for teaching electric circuit	2	6	5	1	6
I experience challenges when teaching concepts such as potential difference, emf, current and resistance to Grade 10 learners	0	11	2	6	1
When teaching the topic of electric circuits, I often use investigations to help learners understand the concepts	3	12	1	4	0
My learners are able to assemble circuits in series and in parallel.	2	5	6	4	3
My learners are often able to relate the concepts of electric circuits to examples in everyday life	1	6	7	5	1

My learners struggle to make links between the concepts in electric circuits with real life situations	4	4	5	7	0
I use different teaching methods to make electric circuits interesting	4	10	3	3	0
My learners do not enjoy learning about electric circuits	1	7	8	2	2
CAPS allocates enough time for the teaching and learning of electric circuits	2	8	5	4	1

Challenging concepts of electric circuits

The findings from the questionnaire showed that 11 out of 20 teachers agreed to experiencing challenges with electric circuit concepts as shown by table 9 above. Consistent with this finding, the interview responses showed that the teachers experienced challenges in teaching concepts such as current, voltage, potential difference and internal resistance. Some of the interview responses are shown below:

Researcher: what concepts of electric circuits do your learners struggle with?

Teacher 1: *The learners struggle to understand whether or not current, voltage stays the same in the parallel and series circuits*

Teacher 2*:* My *learners struggle with understanding potential difference and voltage, because they are similar so they can't differentiate between the two*

Teacher 3*: Finding effective resistance for resistors connected in a combined or mixed network. They get confused whether to start finding total resistance for the parallel connection before including the series one or vice versa.*

Teacher 4*: The learners struggle to identify the branches of the circuit where potential difference is the same and where it divides, likewise with current flow*

The above responses suggest that the learners seem to struggle with the understanding of series and parallel circuits, especially with regards to the effects of current and voltage in these circuits, i.e., whether or not current and voltage stays the same or changes in a series or parallel circuit. Furthermore, the learners have difficulties with interpreting mixed circuits, as indicated by Teacher 3 above. In the questionnaire responses, only 7 out of 20 participants (table 9) indicated that they felt their learners were able to assemble electric circuits in series and parallel. This observation can also be considered one of the factors affecting the learners' understanding of series and parallel circuits because they engage with them only at a theoretical level.

The data from section 2 of the questionnaire showed that some teachers also had challenges in determining whether potential difference changes or remains the same in parallel circuits, for example, one of the questions in the questionnaire (appendix 3), required teachers to interpret an electric circuit and choose the correct answer. The question aimed to understand how the teachers interpret voltage in the circuits. The correct answer was option B (in red), as shown by figure 6 below.

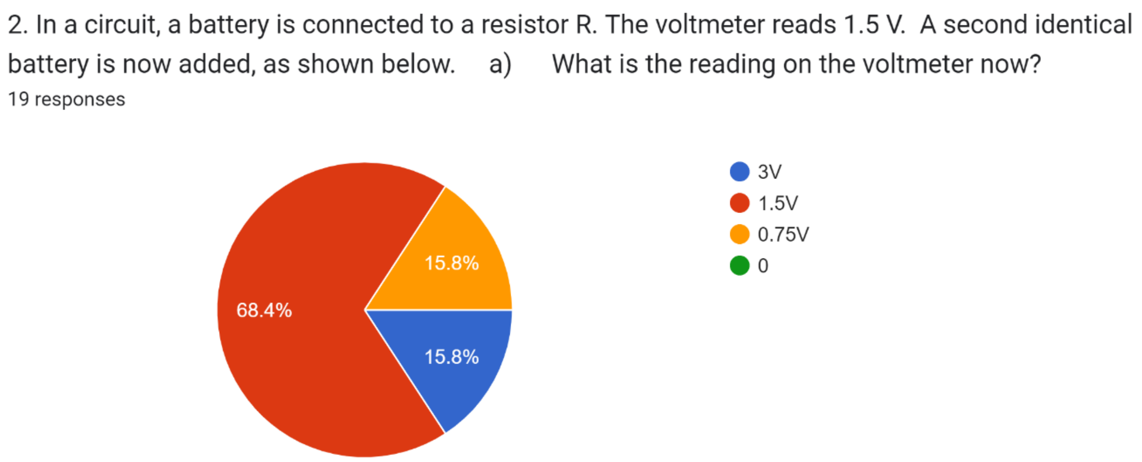


Figure 6: Teachers' responses to a content question in relation to voltage

Although a significant number of the teachers got the answer correct, which shows an understanding of the effect of adding batteries in parallel circuit, however, there were some teachers that got the answer wrong as shown by figure 6 above. The results were indicative of that some teachers do have content gaps in electric circuits, as such this has an impact on how the learners understand the topic of electric circuits.

<u>Learner's Prior knowledge about electric circuits</u>

All five teachers in the interviews indicated that learners have misconceptions and knowledge about electricity from everyday experiences. The interview responses also showed that the teachers attributed the conceptual challenges they experienced to the learners' everyday experiences of electricity. Teacher 3 stated that:

‘‘*learners come to class already having an idea about electricity, some ideas are wrong and make it difficult for the learners to understand”*

This response indicated that the teachers are aware that learners come with prior knowledge to the class and that at times this prior knowledge can hinder the conceptual understanding of electric circuits. When asked what prior knowledge they have picked up from their lessons, the following responses were recorded:

Teacher 1*: For example, when the electric meter box is out of token, they believe that there's no electricity and when they go buy tokens, they say that they bought electricity, so all these contribute to challenges when teaching the actual scientific concepts”.*

Teacher 4: *Learners always think that when the bulbs are not brightly lit when the switch is on, it means that electricity in the circuit is finishing*

The above responses links with the misconceptions that the teachers highlighted in the interview responses, where teachers indicated that the learners seem to believe that charge finishes in the circuit. This is because the learners view charge as being provided by the battery. Some of the teachers' responses are shown below:

Teacher 2: *the learners think that the battery is the source of current flow in the circuit and that charge will finish in the circuit*

Teacher 3: *it is the idea that electricity finishes in the circuit*

The above misconceptions pose an obstacle for the teachers, as the learners struggle to understand the idea of charge in the circuit and most of the time charge is interchanged with current. This can be as a result of the definition of current in most textbooks, for example, in Siyavula- Everything science grade 10 (Hornet et al, 2011, p. 277) current is defined as "the rate at which charges move past a fixed point in a circuit". With this definition in mind, the teacher needs to distinctly differentiate between current and charge for conceptual understanding of electric circuit. Furthermore, current is viewed in relation to voltage and potential difference.

The questionnaire responses also highlighted that the idea of charge was not only difficult for the learners to grasp, however, some teachers also believed that charge gets depleted in the circuit as current flows. This was seen by the responses given in question 4 of the questionnaire (appendix 3), where the teachers were required to explain how they would correct the misconception posed by the water analogy in relation to charge-. The responses are highlighted in yellow in figure 9 below:

P1-Yes, the charge also decreases"

P2- "Charges are always available but if the we don't have the battery, charges will not flow."

P3- "No it doesn't get finished. Charge cannot be created or destroyed. I would like to go further but this analogy I try by all means to avoid since it creates misconceptions."

P4- "The charge gets lower until we refill the water tank".

P5- "In a circuit charge is always present because these are electrons moving in the wire. The battery is not the source of charge"

P6- "Electrons or charge are not used up in an electric circuit because they the energy throughout the circuit. The charges are not the actual source of energy"

P7- Although the analogy is useful, however I would explain to the learners that the analogy is only used to make things simpler and is not an actual circuit. Therefore, in a real circuit charge does not finish because it is always in the circuit. The only thing that finishes is the energy from the battery

Figure 7: Teachers' responses to the water analogy misconception

One observation from the teachers' explanations, was that although a number of teachers were able to provide decent explanations (see figure 7), however, these were brief and had an underlying assumption that the learners fully understand the electric circuit concepts. For example, participant 2 (P2) said they would say that *"Charges are always available but if we don't have the battery, charges will not flow"*. This response suggests that the teacher assumes that learners understand what charge is and, in my opinion, does not fully explain why charge does not finish in the circuit. The vague explanations of the charge misconception could be from the fact that most teachers have difficulties with the water analogy (Osborne, 1983). The water analogy is one of the analogies commonly used in the textbooks to explain the flow of current in the circuit. A study by McDermott (1982) found that most teachers avoid this analogy as they feel it creates misconceptions. It was also observed from figure 9 above (green) that some teachers also shared the same sentiments. Furthermore, some teachers avoid this analogy because they themselves hold the idea that current gets used up as it flows through the circuit (yellow).

When teachers have misconceptions of the concepts, it negatively affects the teaching and learning of electric circuit concepts. Where some of the misconceptions are perpetuated to other grades or related topics in the syllabus, such as electromagnetism. Moreover, it may also result in some topics being rushed over or entirely skipped as the teachers avoid exposing their poor knowledge of a topic.

Apart from the charge related misconceptions, the interview responses indicated a number of misconceptions as shown below.

Teacher 2*: Learners think that direction of conventional flow is from the negative terminal of the battery towards positive terminal, where as it flows from positive to negative*

Teacher 3*: when the cell is labelled 1.5 V, they think it provides1.5V in the external circuits and it's so hard for them to believe the concept of internal resistance that decreases the EMF of the cell.*

Teacher 5*: one misconception that the learners have is that the more batteries you add in a circuit, the bigger the voltage regardless of whether it is a parallel or series connection*.

The idea of internal resistance is one that is often challenging for the learners. The response from teacher 3, shows that the learners neglect the effect of internal resistance in the circuit. When looking at the CAPS Grade 10 curriculum, it mainly focuses on concepts such as current, charge, potential difference, voltage and resistance. The content does not go deep into concepts of internal resistance and EMF as shown in figure 8below. The concept of internal resistance is covered in detail in Grade 11. As such learners' having difficulties understanding the effect of internal resistance on EMF could be complex for the learners at this stage, hence the misconception highlighted by Teacher 3.

Time	Topics Grade 10	Content, Concepts & Skills	Practical Activities	
1 hour	Resistance	• Define resistance • Explain that resistance is the opposition to the flow of electric current • Define the unit of resistance; one ohm (Ω) is one volt per ampere. • Give a microscopic description of resistance in terms of electrons moving through a conductor colliding with the particles of which the conductor (metal) is made and transferring kinetic energy. • State and explain factors that affect the resistance of a substance • Explain why a battery in a circuit goes flat eventually by referring to the energy transformations that take place in the battery and the resistors in a circuit		
2 hours	Resistors in series	• Know that current is constant through each resistor in series circuit. • Know that series circuits are called voltage dividers because the total potential difference is equal to the sum of the potential differences across all the individual components. • Calculate the equivalent (total) resistance of resistors connected in series using: $R_s = R_1 + R_2 + \ldots$	**Prescribed experiment:** (Part 1 and part 2) **Part 1** Set up a circuit to show that series circuits are voltage dividers, while current remains constant	M L s a

Figure 8 Shows an image from the Curriculum Assessment Policy Statement (CAPS) for grade 10-12 physical sciences

Challenges with Mathematical operations

One other barrier to the conceptual understanding of electric circuits that emerged from the findings was the learners' poor mathematic skills. Retnawati &Arlinwibowo (2018) assert that mathematics is a big aspect of science understanding. Table 10 below shows that a significant number of teachers feel that their learners struggle with calculations in electric circuits.

Table 10: Teachers' responses on the challenges in relation to calculations

Question	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
5.My learners are able to interpret electric circuits and do calculations	2	9	7	2	0
6.My learners struggle with calculations in electric circuits	1	11	4	3	1

Similar sentiments were shared by some teachers in the interview responses, where Teacher 2 indicated that "*Learners can't do simple calculations; they need to be guided through all the questions in order to get the answer"*. Calculations are an important aspect of electric circuits. In most textbooks, the relations between current, voltage and resistance are expressed in mathematical format, for example Ohms law. Furthermore, assessment questions about electric circuits always include calculations. The interview responses attributed the lack of mathematical skills to the learners' reliance on the internet for answers. Teacher 5 stated that "*when you give them an activity, they are quick to take out their phones and google the answers".* Teacher 1 also concurred with this view by saying that *"Learners often just type in the question on the phone and copy and paste the answer in the book"*.

5.3 Factors contributing to the challenges experiences

5.3.1 Lack of well-resourced facilities

According to the findings of this research study, there is a number of factors contributing to the challenges experienced by the novice teachers when teaching electric circuits. One of the factors is the lack of well-resourced facilities. Table 8 shows that most teachers agreed that the lack of resources affects their teaching as the teachers are unable to use practical activities in order to teach electric circuits.

Table 11: Teacher responses from the questionnaire in relation to lack of resources.

Questions	Strongly agree	Agree	undecided	Disagree	Strongly disagree
The problem of resources affects my teaching of electric circuits	6	11	0	2	1

5.3.2 Teachers' teaching approaches

The findings also indicated that the teachers' pedagogical approaches influenced the learners understanding of electric circuits. Findings from the interviews showed that most of the teachers used teacher centred approaches. The approaches mentioned were, question-and-answer, explanations, discussions and only Teacher 2 mentioned that they used demonstrations. The teachers' responses are shown below:

Researcher: What approach do you use when teaching concepts such as current, potential difference and resistance?

Teacher 1*: "I do discussions where learners will express what they already know and believe about the concept of electricity. I then build up my lesson based on their knowledge and that time I infuse direct instruction approach, where I then teach them what is correct according to the concepts.*

Teacher 2*: I try to do demonstrations using electric circuits…I feel learners understand more when they see the circuits*

Teacher 3*; I first introduce the concepts by explaining what they mean and then I use drawings on the board to explain the concepts in relation to the parallel and series circuits*

Teacher 5*: I use question and answer and the narrative approach*

The approaches mentioned above (question and answer, narrative, explanation) are linked with direct instruction and encourage rote learning. Moreover, the approaches also indicate the lack of use of practical activities. However, the findings show that, with some teachers the lack of practical activities is a result of contextual factors like the lack of lab equipment. Teacher 3 stated that:

> "*I would like to do investigations with the learners but our school has no equipment, so I just go through the investigation in the textbook with the learners".*

The lack of practical activities has implications on the teaching and learning of electric concepts because it means that the learners are only engaging with the concepts of electric circuits at an abstract level, for example, one cannot visibly see the flow of charge.

Similarly, findings from the questionnaire responses (refer to table 3) indicate that most teachers admit that the lack of resources affects their teaching of electric circuits. This gives the assumption that the availability of resources has a direct impact to how electric circuits is taught. Drawing from my teaching experience both as a preservice and qualified teacher, learners from well-resourced schools experience education differently from those in under resourced schools. In the same line of thought, it is also important to acknowledge that the teaching approaches mentioned by the teachers (narrative, question and answer) also play a vital role in the lessons, depending on the teachers' intentions, for instance, using question and answer to illicit the learner's prior knowledge as indicated by Teacher 1 above, as well as making connections between the content and what the learners already know.

Contrary to the findings from the interviews, the questionnaire responses indicated that although most teachers stated that they did not have adequate resources to conduct investigations, however, 15 out of 20 teachers (table 2) indicated that they used investigation to teach electric circuits. This could mean, going through the investigations in the textbook and not actually doing them, as alluded to by teacher 3: "*.... I just go through the investigation in the textbook with the learners".*

The above finding was also supported by the finding that teachers indicated (table 8) that they found other alternatives when they run out of resources. One of the alternative resources alluded to by the teachers in the interviews was online videos.

Teacher 1: *I enforce understanding through visiting external sources such as online videos, where learners get the chance to visually see what is happening"*

Teacher 2*: I use videos and bring visual pictures to show learners what I am explaining.*

Teacher 4*: sometimes I just get YouTube videos of an expert explaining the concept because maybe they do not understand how I explain it.*

The teachers teaching approaches are also influenced by the teachers experiences of electric circuits both as a learner and as a preservice teacher in university. Teacher 5 stated that *"back in my day, we did not do any practicals in the class, we just read from the textbook"*. Similarly, Teacher 3 commented that:

> "*I don't remember doing praticals for electric circuits in varsity and it is difficult to also find resources to do these practicals*".

As such one would expect a seldom use of practical activities in these teachers' lessons because the teachers cannot conduct practical activities if they were not taught how to. Findings from the questionnaire concurred with this observation, where most of the teachers felt the university did not prepare them enough for the teaching of electric circuits. In this case, only 8 out of 20 teachers felt they adequately prepared for the teaching of electric circuits (see Table 9). Moreover, this finding is further backed by the responses from section 2 of the questionnaire, where the teachers were expected to match the schematic diagram with the realistic circuit shown. In this question, the correct answer for this question was option B. According to the results, none of the teachers got the answer correct. The teachers were unable to translate from a schematic representation to a realistic circuit. As shown by figure 9 below.

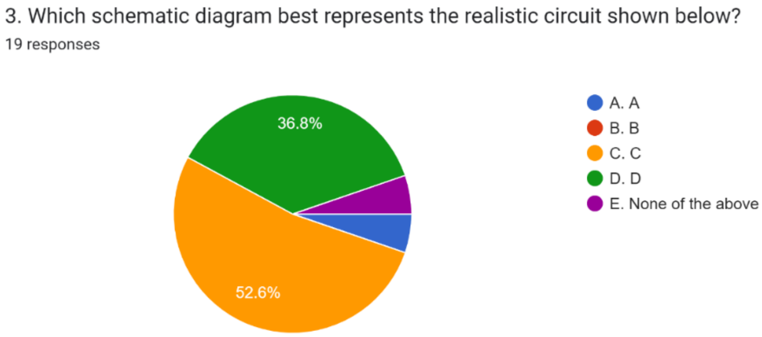


Figure 9: Teachers' responses to the question on schematic diagram and realistic circuit

The results suggest that it is expected that the learners will also struggle with such questions, as teachers cannot teach something that they themselves do not know. The use of practical activities may perhaps make it easier for the teachers to match these representations as well as help learners understand circuits more. There needs to be explicit training given to teachers about the incorporation of practical activities in the teaching of electric circuits. More especially with the use of alternative resources.

5.3.3 Learner's lack of interest in electric circuits

One major observation was that the teachers acknowledged that the learners did not find the topic of electric circuits interesting, for example, Teacher 1 stated that "*they have as short attention span so they get bored very easily, especially during the long periods"* Teacher 4 concurred that "the *learners get bored, especially when they sit and listen to the teacher talk especially during the long periods".* This finding was also consistent with the questionnaire responses that indicated that the learners did not find the topic of electric circuits interesting. Here only 4 out of 20 teachers felt that they learners thought electric circuits are interesting (see table 9). This could be linked to the teachers' dominant use of teacher centred approaches, as learners are normally passive participants in these lessons.

Moreover, the teacher responses also attribute the lack of interest from the learners to their short attention span as indicated by Teacher 4's response *"They have a short attention span so they get bored very easily, especially during the long periods".* This response suggests that the teacher believes that making the lessons interesting can help the learners pay more attention in class. The challenge then seems to lie in how to make the topic of electricity more interesting to the learners. One suggested way is to incorporate ICT in the teaching of electric circuits.

5.3.4 Teachers not prepared to teach electric circuits

The novice teachers interviewed in this study highlighted that they felt underprepared not only for the school context but also for the teaching of electric circuits. Some teachers stated that they did not get proper training from the universities especially in doing practical activities.

Teacher 3: *I don't remember doing praticals for electric circuits in varsity and it is difficult to also find resources to do these practicals*

Teacher 5: *In university they did not teach us how to do investigations in electric circuits, we just looked at the knowledge.*

This lack of preparedness influences the confidence of the novice teachers in lesson delivery, as the teachers prefer not uses teaching methods that will expose their weaknesses in teaching.

5.3.5 Teachers attitudes towards teaching electric circuits

The findings from this study reveal that some teachers had negative attitudes towards the uses of practical activities in the teaching of electric circuits.

Teacher 1: *practical work needs time and can take the whole day*

Teacher 3: *when learners do practicals, it gets noisy and sometimes we don't finish in time*

The view that practical work is time consuming could be a result of firstly, the lack of knowledge on how to conduct practical activities and secondly the belief that electric circuits is best taught through direct instruction. It is also important to note that the teachers believed that they did not have enough time to cover the topic and thus the disregard of practical activities when teaching electric circuits could be caused by the time constraints and pressure to meet assessment deadlines.

5.4 How do physical sciences novice teachers address these challenges?

When encountering challenges when teaching electric circuits, 17 out of 20 respondents agreed that they used alternative resources, as shown by the table below

Table 12: showing responses on alternative resources

Questions	Strongly agree	Agree	undecided	Disagree	Strongly disagree
I do not have the resources to conduct investigations when teaching electric circuits	8	6	2	2	3
There are other alternatives I use when I run out of resources	3	14	2	0	1

Majority of the teachers admitted to not having enough resources to teach electric circuits, similarly most teacher also agreed that they used alternative resources when they encounter red challenges with the lack of resources. Even though these were not specified, however this showed agency and willingness on the teachers' part to provide a sufficient experience of the topic of electric circuits to the learners. Data from the interviews also concurred with this finding. Below are some of the responses from the interviews.

Teacher 1: *I enforce understanding through visiting external sources such as videos, where learners get the chance to visually see what is happening*

Teacher 2: *I outsource different resources to do with the concept of electricity and I go through the concept with the learners trying to enforce understanding. I also download videos that we watch and listen to how other experts explain and attack the problems or challenges.*

Teacher 3: *when learners do not understand the concept I do a step-by-step analysis. I draw different circuits on the board and explain to the learner's step by step, thus helps them to understand easily.*

Teacher 5: *I go back to visuals and also give real life examples*

Additionally, the findings from the study show that teachers mostly used ICT methods to resolve the challenges of lack of resources. Furthermore, the findings also revealed advantages and disadvantages of the use of ICT in the classroom as per the teachers 'experiences as well as in relation to the generation Z learners. Findings from the questionnaire responses indicate that the teachers believe that the incorporation of ICT is beneficial to the learners (see table 12), as the teachers believe that ICT would make the topic of electric circuits interesting and keep the learners engaged in the lesson. The questionnaire responses also showed that there were teachers that used ICT methods in their teaching, as well as those that did not, where 9 out of 20 teachers agreed to incorporating ICT in their lessons.

Table 13: Teachers' responses on the use of ICT in teaching electric circuits

	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
I incorporate ICT when teaching electric circuits (videos, simulations, other online resources)	3	6	4	5	2
I find that incorporating ICT in my lessons keeps the learners engaged	2	9	7	1	1
ICT is a distraction for learners in my classroom	1	3	6	6	4
When given tasks, my learners rely on their phones more than other resources such as textbooks	1	6	4	7	2

In the interview responses, although the teachers stated they used ICT methods in their teaching, however it was to a lesser extent as they mostly used the direct instruction approach. In one of the interviews Teacher 5 commented that "*I have never seen ICT being used to teach electric circuits"*. This response suggests that the incorporation of ICT in the classroom is also influenced by the teachers' identity and teacher training, for example, if the teachers are not explicitly exposed to ICT in their schooling experience it presumably also is difficult for them to use these strategies in their teaching approaches. In my schooling experience, despite having computers and internet access at school, the teachers hardly used the computer centres. This calls for more exploration of science teachers' Technological Pedagogical Content Knowledge (TPACK).

Another finding from the interview responses was that, when the teachers spoke about incorporating ICT they mostly spoke about the use of online videos. In actual fact, the teachers stated that they used online videos to explain difficult concepts in the lessons as shown by the responses below:

Researcher*: What strategy do you use to explain a difficult concept?*

Teacher 1: *I enforce understanding through visiting external sources such as online videos, where learners get the chance to visually see what is happening"*

Teacher 2*: I use videos and bring visual pictures to show learners what I am explaining.*

Teacher 3*: I come with my laptop and show them videos or just hotspot them so they can watch the videos on their phones*

Teacher 4*: sometimes I just get YouTube videos of an expert explaining the concept because maybe they do not understand how I explain it.*

The above responses show a linear view of ICT teaching methods, for example, the teachers view ICT only in terms of videos and visuals. Njoko (2018) asserts that there are multiple ICT teaching strategies that can be use in the classroom, such as using online quizzes, simulations as well as educational games. In the same breath, I acknowledge that the lack of computers and smartboards in most schools (figure 4) may contribute to these methods not being used in the classroom.

Moreover, the interview responses also indicated a level of hesitation with the incorporation of ICT in teaching electric circuits, despite agreeing that it would beneficial to their teaching. This hesitation was largely related to the learners' behaviour.

Teacher 1: "*The current generation is very ill-disciplined and lazy, because when you give them an activity, they are quick to take out their phone s and google the answers, whilst back in my generation we would actually sit and think on how to resolve the question"*

Teacher 3*: They are negligent sometimes, when you teach, they don't put more focus because they know they can go through the internet and read*".

Teacher 5*: The current generation do not pay attention in class and most just copy and paste answers from the internet*

Another reason for the teachers' hesitation for using ICT methods, according to the interview responses was that ICT methods require a lot of preparation, Teacher 3 stated that "*ICT needs time and the learners get easily distracted, that moment we have to complete the syllabus".* In this case, one thing to consider is that despite the teachers being technologically inclined themselves, one cannot assume that they have the necessary technological knowledge to incorporate ICT in their lessons. Furthermore, in contrast to Teacher 3's comment, the questionnaire response indicated that the CAPS curriculum allocated enough time for the teaching of electric circuits, where half of the participants agreed they had enough time to teach electric circuits (table 9). Keeping this in mind, it can be assumed that with the correct technological knowledge and resources the teachers can successfully incorporate ICT in their teaching.

5.5 A summary of the findings using critical realism

Interrogating the challenges experienced by the novice teachers when teaching electric circuits, one can argue that the challenges are as a result of underlying factors. The challenges go beyond what can be seen on the surface, which is the tangible factors resulting in these challenges. The hidden factors such as the attitudes toward electric circuit, the teachers' feelings of being inadequately prepared to teach electric circuits, the influences that come with the generation Z learners. This study argues that the challenges experienced by novice teachers should be looked at from a microscopic view to unearth the root causes and consequently mitigate these challenges.

Bhaskar (1978) posits that when we recognize that reality is multifaceted, meaning that something can exist at one level and also appear in different ways at another level. An example of this could be seen through what the novice teachers envisioned about the school context prior to entering the teaching field was somewhat different to what they experienced in the actual settings. In this sense it is also apparent that in each level of reality (empirical, actual, real) there are underlying factors that influence how the different groups of teachers experience teaching in different school contexts. Extending from this view, Cochran-Smith et al (2014), asserts that Critical realism is an important aspect of teacher educational research as it provides a critical perspective of how systems work in schools and what makes them work in the first place. Looking at the study from a critical realist view, by means of stratified realities, this study explored the challenges faced by the novice teachers, this including the beliefs the teachers attach to electric circuits, the contextual factors, content related factors and how the teachers addressed these challenges, which formed part of the agential mechanism. All these aspects shape challenges experienced by the novice teachers. In aligning with the critical realist perspective, the findings are looked according to the layers of reality below.

5.5.1 The Three levels of reality: Empirical, Actual and the Real

The first level is the empirical level, this level represents the experiences relating to physical objects. At this level, the contextual challenges are recognized such as the lack of teaching and learning resources (textbooks), the lack of adequately equipped basic infrastructure such as laboratories to perform investigations. These contextual aspects affect the kind of teaching approaches that the teachers used to teach electric circuits. The findings from this study reveal that these factors limit the teachers to teacher-centered approaches.

The second level, which is the actual refers to the teachers that result in what is observed in the empirical level. In this study this level refers to the factors that make the teaching and learning of electric circuits complex, such as the learner prior knowledge, which in most cases resulted in misconceptions, the teaching approaches, which as a result of lack of resources, attitudes towards electric circuits and a lack of content knowledge resulted in a dominant use of teacher-centered approaches. The teaching approaches consequently also influenced the learners' interest in the topic of electric circuits. The lack of interest also seemed to link with the learners technological inclined nature and a lack of attention span. According to Akabor (2020, p.205), "events in this this level are not easily changeable and flexible, and remain consistent"

The third and last level of reality, also the deepest level encapsulates three mechanisms, the cultural, structural and agential mechanisms. The cultural mechanism involves the attitudes and beliefs of the novice teachers towards the teaching of electric circuits. These attitudes and beliefs influence how the novice teachers approach electric circuits and how they handle the challenges encountered when teaching electric circuits. The structural mechanism consists of the actual context and content difficulties in relation to electric circuits, including the processes and procedures that are involved in teaching electric circuits. The agential mechanism speaks to how the individual teachers respond to both the cultural and structural mechanisms. The way in which the teachers respond to the challenges experienced can either "transfer in or reproduce the original structure". The diagram below shows a summary of the interactions of the three mechanisms.

Table 13: Display of some findings using the analytical framework

Empirical	**Observable challenges experienced by teachers as a result of tangible factors**
	The lack of teaching material such as textbooks, electric circuit as well as the lack of fully functional infrastructure to conduct practical activities such as laboratory
Actual	**Events happening at the school that lead to the empirical level regardless whether the teachers experience these events or not**

	Teachers lack of adequate content knowledge, the knowledge that learners bring to classroom, the teaching approaches, uses of direct instruction, difficulties with the calculations and the representations		
Real	**Cultural mechanisms**	**Structural mechanisms**	**Agential mechanisms**
	Finding 1: Many schools lack adequate or functional teaching and learning resources		
	• Attitudes towards lack of resources • Mishandling of the resources	• Poor service delivery • The crime rate in the communities • Damage to the teaching materials	• Use of alternative resources • Lack of improvisation
	Finding 2: Basic concepts of electric circuits are difficult for both teachers and learners		
	• Belief that science is complex and boring • Feeling of inadequate with content knowledge	• Content gaps from teachers • Lack of practical activities • Less usage of representation such as schematic diagrams	• Lack of confidence in pedagogy • Teachers not prepared for teaching of electric circuits
	Finding 3: Both teachers and learners struggle with mathematical operations related to electric circuits		
	• Calculations are seen to be difficult	• Difficulties interpreting the circuits	• Dominant use of the internet for solutions

	• Difficulties conceptualizing the electric circuits	• Lack of conceptual understanding of calculations and equations such as ohms' law	
	Finding 4: Teaching approaches used in teaching electric circuits can be problematic for the learners		
	• Dominant uses of traditional methods • Lack of confidence in content knowledge	• Lack of textbooks • Lack of specialized resources like laboratories	• Insufficient use of improvision • Use of online videos to explain concepts
	Finding 5: Learners have a lack of interest in the topic of electric circuits		
	• Abstract nature of electric circuits • Attitudes to was alternative teaching methods	• Learners' low attention span • Electric circuits seen as complex.	• Use of direct instruction • Incorporation of ICT tools in teaching
	Finding 6: Incorporation of ICT in teaching electric circuits is problematic for the teachers		
	• ICT a distraction for learners • Belief that ICT time consuming and	• insufficient knowledge of ICT • inadequate ICT resources	• Use of online videos • Use of simulations to explain

	requires a lot of preparation		complex concepts

5.6 Chapter summary

Relevant data from the study has been presented and analysed in this chapter. The findings show that Grade 10 novice physical sciences teachers experience challenges mostly involving contextual factors as well as content related challenges. Some factors revealed to be contributing to the challenges included misconceptions, inadequate content knowledge, as well as the lack of resources, which heavily influenced the teachers' teaching approaches. In the next chapter, the data presented in this chapter is discussed. Moreover, recommendations are given as per the findings.

CHAPTER 6

SUMMARY OF FINDINGS AND CONCLUSIONS

6.1 Introduction

The purpose of this study was to explore the challenges experienced by Grade 10 Physical Science novice teachers when teaching electric circuits. Furthermore, the study aimed to unearth the factors contributing to these challenges and how the teachers overcome the challenges. In the previous chapter, the findings of this study were presented and discussed. In this chapter, the overall findings of this study are summarized. In addition, this chapter provides recommendations and limitations of the study.

This study intended to answer the following main research question: **How do grade 10 novice physical sciences teachers perceive the challenges they encounter while teaching electric circuits to generation Z learners?**

In so doing, the following sub-research questions were explored:

1. What challenges do the Physical Science novice teachers say they experience when teaching Electric Circuits to the generation Z learners in Grade 10 science classrooms?
2. What factors do the Physical science novice teachers attribute to the challenges experienced during their teaching of electric circuits?
3. How do Physical sciences novice teachers address these challenges?

In chapter 3, the theoretical framework that guided this study was discussed. The concepts of Critical realism as proposed by Bhaskar (1978) helped to understand the challenges experienced by the novice teachers in relation to content knowledge as well as pedagogical practices. The researcher also looked at the teachers' technological knowledge although to a lesser extent. With the critical realist concepts in mind, the data collected from the questionnaire and semi-structured interviews were analysed. Using the sub-research questions that guided this study, the findings are summarized below.

6.2 Challenges experienced by Physical science novice teachers when teaching electric circuits.

6.2.1 Contextual Challenges experienced by novice teachers.

In this study, the novice teachers experienced challenges with the availability of resources, especially specialized resources such as laboratory equipment despite having laboratories in their schools (refer to table 6). As such, these laboratories were used for other purposes such as storing outdated textbooks and other materials not used. Legari (2004) and Muyambano (2019) assert that the lack of resources is one of the greatest obstacles in the teaching of physical sciences, furthermore, the lack of resources limits the teachers' ability to do practical activities with the learners. Muyambano (2019) further states that, the lack of practical activities, results in learners not having conceptual understanding of the concepts because they remain only at an abstract level.

Types of resources	**Availability of resources (%)**
Electricity	100%
Sufficient water	85%
Enough textbooks for learners	65%
Library room	70%
Laboratory	70%
Enough laboratory equipment	15%
Other relevant teaching aids (charts, interactive worksheets)	20%
Computers for learners	25%
Access to the internet (Wi-Fi)	15%
Smart boards	35%

Table 14: Summary of questionnaire data on the availability of resources

What was also evident from the study is that, not all the schools had access to adequate textbooks for the learners (table 14). Access to textbooks was an important factor to teachers as some of the teachers heavily relied on the textbooks for teaching and learning of electric circuits, The shortage of textbooks was as a result of theft, learners mishandling the textbooks and the lack of service delivery from the Department of Basic Education. According to Legari (2004), poor service delivery from the department has detrimental effects on the South African school system as it perpetuates inequalities between private and public schools. Learners in private schools mostly learn science by 'doing', due to the easy access to resources while learners in most public schools learn science through rote learning, owing to a shortage of learning material. Furthermore, the effect of these inequalities is also experienced in tertiary level, where there is a gap between knowledge and skills possessed by students from affluent schools and those from under-resourced schools, for example, drawing from my first-year experiences in tertiary level, it was noticeable that other students from affluent schools had a better understanding of practical sessions as compared to us from the public schools. This was because we first needed to be schooled on the laboratory rules, the different types of apparatus as well as the handling of the apparatus before actually doing the practical as these were new to us.

The lack of service delivery also affects the teaching and learning of science not only through the lack of resources to do practical tasks but also the shortage of textbooks affects the basic instruction of the teacher in the classroom, for instance, science is mostly abstract in nature (electrons moving in the conducting wires) and thus teachers mostly refer to representations in the textbooks to aid their explanations of concepts, therefore it becomes difficult to make reference to information in the textbook when learners do not have access to the textbooks. Secondly the shortage of textbooks slows the syllabi completion as the teachers move at a slower pace to accommodate the learners that do not have textbooks, resulting in other concepts being brushed over in a bid to keep up with the curriculum coverage and lastly it has negative impact on the learners' performance as learners primarily use textbooks to study for formal assessment and a learner without one gets disadvantaged as they have limited material to prepare for the assessments.

Findings from the Questionnaire indicated that the lack of resources affected the teachers' instruction, however, some teachers stated that they used alternative resources when they run out of resources although these were not documented. Legari (2004) emphasises that one of the ways to combat lack of resources is improvisation. Improvisation is important so that the learners get a holistic experience of the learning of electric circuits both at an abstract and concrete level.

Another finding in relation to resources was that the schools were mostly poorly resourced with ICT equipment (computers, smartboards, Wi-Fi) for teaching and learning. Zungu (2022) asserts that the uses of ICT resources are beneficial to the teaching and learning of science, as teachers are able to do virtual experiments and use simulations to make learners understand abstract concepts. From the interviews, the teachers stated that the lack of ICT resources is due to theft in the community. Moreover, Njoko (2018) argues that, although one of the aims in the CAPS curriculum is to "promote the construction and application of scientific and technological knowledge" (CAPS, 2011, P.8), most schools in South Africa are still not adequately prepared for the incorporation of technological instruction in the teaching and learning of science. The challenges pertaining to resources, have a direct impact on the teachers' pedagogical approaches as it limits the teachers' teaching strategies mostly to teacher centred approaches and often hinders understanding of the science concepts. Figure 10 presents the summary of the contextual challenges experienced by teachers when teaching electric circuits.

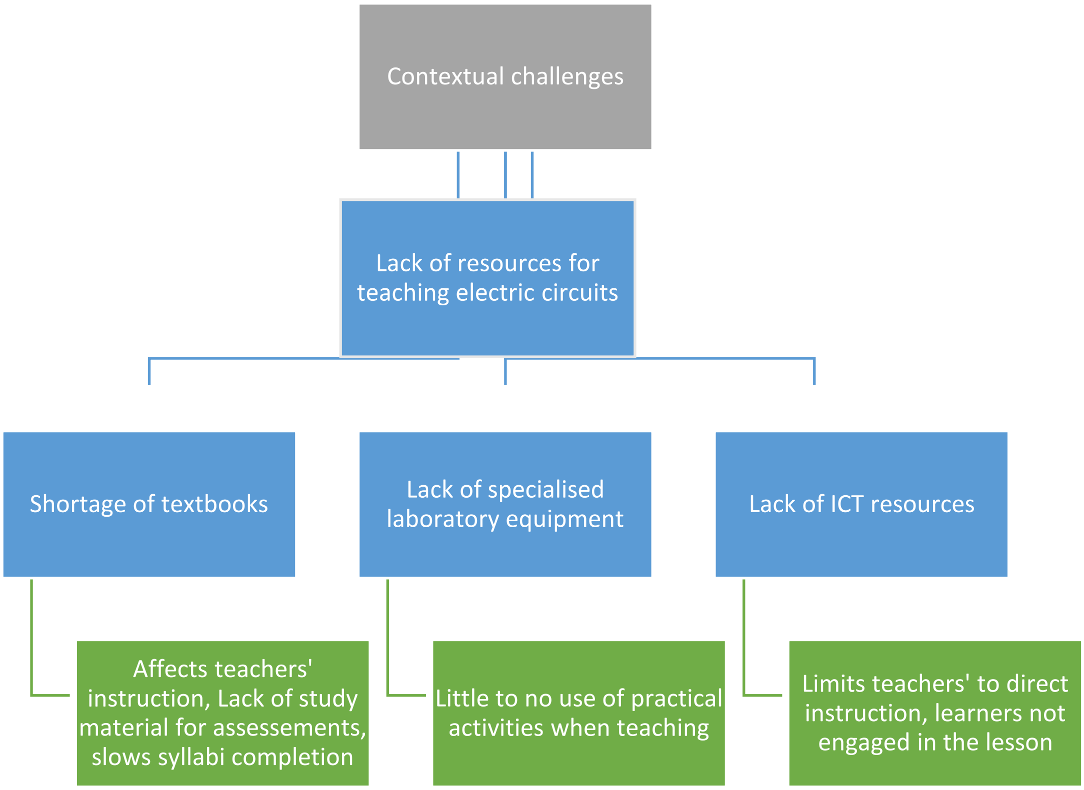


Figure 10 Summary of the contextual challenges and its implication for teaching and learning

6.2.2 Conceptual challenges experienced by the novice teachers

The findings from this study shows that the conceptual challenges experienced by the novice teachers fall into 4 categories: Learner prior knowledge, content knowledge, mathematical operations and teaching approaches. These are illustrated in the model showed below in Figure 11 followed by the findings summarised individually.

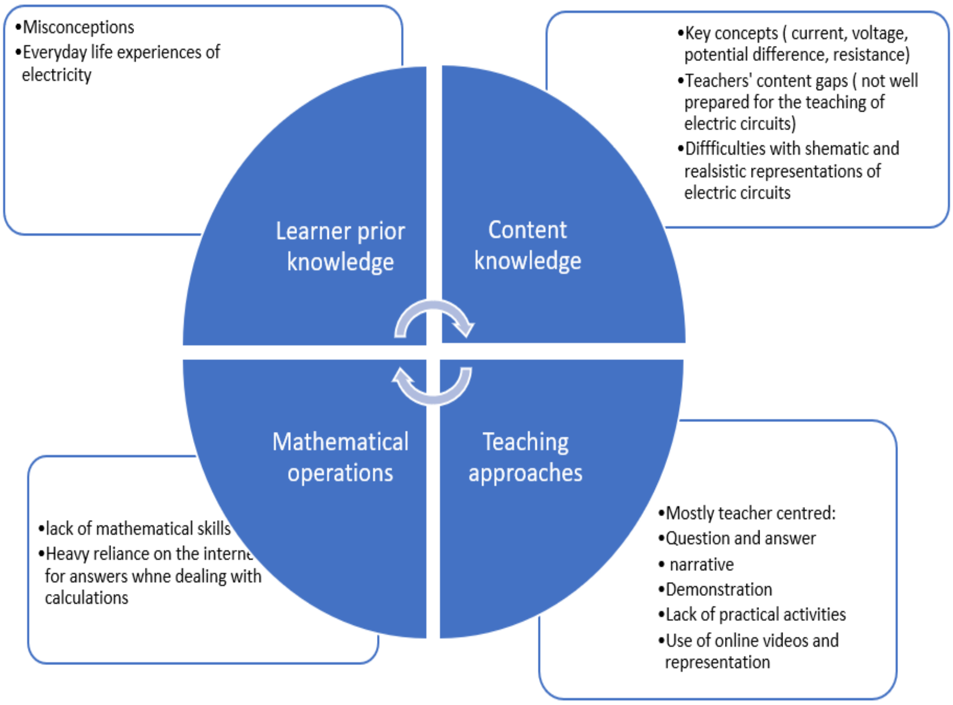


Figure 11: Summary of conceptual challenges experienced by the teachers when teaching electric circuits

Learner prior knowledge

Vygotsky (1978) argues that learners are not empty vessels, as such, they possess prior knowledge from everyday experiences as well as from previous grades. In this study, findings indicated that most of the teachers encountered a variety of learner prior knowledge during their lessons. The learner prior knowledge was mostly from their everyday experiences of electricity, as stated by Teacher 1 "*For example, when the electric meter box is out of token, they believe that there's no electricity and when they go buy tokens, they say that they bought electricity, so all these contribute to challenges when teaching the actual scientific concepts".*

Learner prior knowledge was one of the main sources of misconceptions from the learners. This made the teaching of electric circuits challenging. Mavhunga (2012) posits that, learner prior knowledge can hinder or enable conceptual understanding of the concepts. Furthermore, it was also observed from this study that that misconceptions were not only limited to the learners but some teachers also held misconceptions about electric circuits, one of them being that “charge gets depleted in as current flows in the circuit”. Moodley (2014) argues that misconceptions from the teachers contribute to the challenges experienced by the novice teachers as they influence the learners’ understanding of the concepts.

Content knowledge

One of the major findings of this study was that the teachers’ experienced challenges in teaching concepts such as current, voltage and resistance. From the findings in this study, it was deduced that most of the challenges stemmed from the learners’ failure to interpret series and parallel circuits, where learners have difficulties understanding whether current, volage increases or decreases when components such as batteries are added to the circuit. In relation to current, most of the challenges were also as a result of the lack of understanding of charge.

Moodley (2014) argues that learners often interchange current and charge leading to a partial understanding of the distinction between the two. Furthermore, findings in the study also revealed that some teachers share the same difficulties with the learners, revealing that they had content gaps in electric circuits. Moodley (2014) posits that content gaps are detrimental to the teaching of science because more often than not, teachers skip or rush through the content knowledge that they are not confident in at the expense of the learners’ conceptual understanding. Linking to this finding, was that most teachers agreed that they felt that the tertiary institutions did not adequately prepare them for the teaching of electric circuits. Muyambano (2019) states that in most cases, tertiary institutions primarily focus on the theoretical aspects, furthermore, Muyambano (2019) also acknowledged that the tertiary institutions do not have the time or the setting to fully give a holistic experience of the school context and as such most things are learnt in practice.

Mathematical operations

An important finding stemming from the study was also that the teachers felt that their learners struggled with mathematical operations in electric circuits. Retnawati &Arlinwibowo (2018) assert that one of the key aspects to understanding electric circuits is the ability to do calculations. In this study, the teachers stated that the lack of mathematical skills comes from the learners’ nature as digital natives, for instance, their heavy reliance on the internet for answers. Furthermore, the teachers feel that this makes the learners not pay full attention in class due to the easy access to activity solutions online.

Retnawati &Arlinwibowo (2018) argue that teachers themselves are also not confident in mathematical operations related to physical science. in this sense they also struggle to teach learners how to do calculations but rather have the learners memorise formulas. It might be beneficial for the department of education to have workshops aimed at equipping teachers with mathematical operation skills, how to simplify calculations for the benefit of the learners given that mathematics is still one of the subject's learners perform poorly in (Mabena et al, 2021).

Teaching approaches

The teachers' teaching approaches also have an impact on how the learners understand the science concepts. Findings from the study revealed that the teachers mostly used teacher-centred approaches such as question and answer and explanations. Akinyemi (2016) posits that teacher centred approaches limit interactions from the learners during the lesson. What was also evident from the findings was that the teachers acknowledged that the learners did not find the topic of electric circuit interesting, Teacher 4 stated that "the *learners get bored, especially when they sit and listen to the teacher talk especially during the long periods"*. Moreover, this was as a result of their low attention span. Njoko (2018) proposes that ICT methods could be used to make science topics interesting for the learners.

The findings also showed that teachers seemed to have difficulties with matching schematic diagrams of electric circuits with the realistic circuits. In this study, none of the teachers were able to do this, perhaps owing to the lack of practical activities in the classroom, as such the concepts of electric circuits as well as the diagrams are only experienced at a theoretical level. The incorporation of practical activities could help teachers familiarises themselves with circuits beyond textbook diagrams. The teaching of science should shift towards a more practical instruction and thus workshops provided by the DBE should be geared towards this goal

The diagram below (Figure 12) shows a summary of the findings related to ICT use in the teaching of electric circuits. The summary below presents the challenges experienced by the teachers, the benefits of ICT use in teaching as well as the way in which the teachers used/ could use ICT effectively in their lessons in order to minimise challenges of lack of resources and content related challenges.

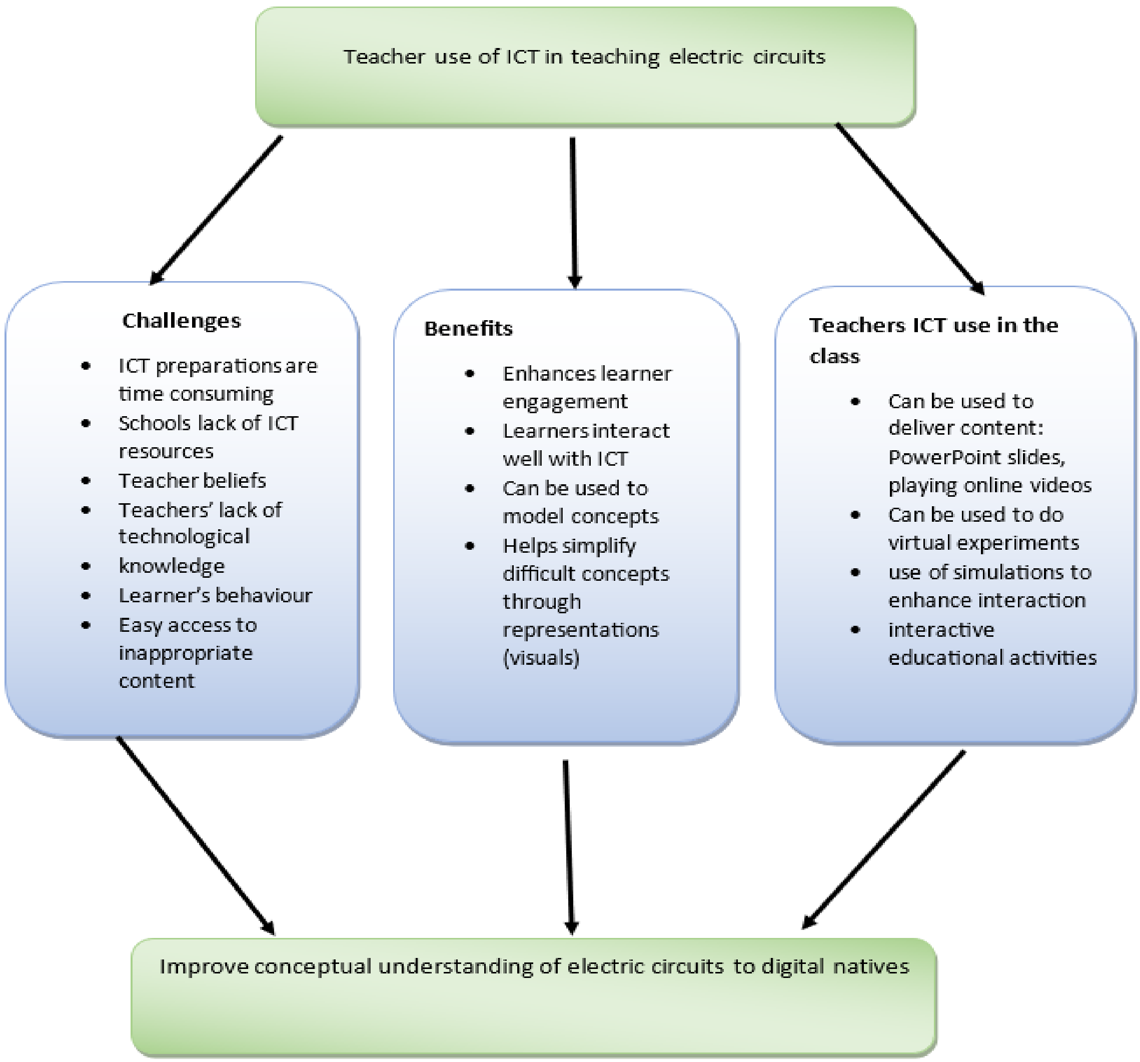


Figure 12 A summary of the Teachers' use of ICT and its implication for teaching and learning

According to this study's' findings, all the teachers found ICT to be beneficial for the teaching of electric circuits. Given the issue of resources, the teachers stated that they used online videos to show learners practical investigations. Furthermore, they used online videos of other experts in science to simplify the difficult concepts. Studies by Ayere et al (2010) and Habbler et al (2016) found that ICT improves understanding of science concepts as learners are able to do virtual experiments. However, as much as this was the case, the novice teachers also expressed hesitation with the use of ICT in their teaching. This was because of the learners not paying attention to conceptual understanding of concepts in the lesson. The lack of attention from the learners is as a result of not being actively engaged in the lesson, as they sit passively watching the online videos. Furthermore, the access to information online contributes to learners not paying attention. This is because they believe that whatever information presented by the teacher can be easily found on the internet. In mitigating this issue, teachers can engage with ICT in ways that are interactive for the learners, using simulations, online puzzles and other educational games that will stimulate participation from the learners.

Other concerns were that ICT methods were time consuming, furthermore, the schools are not well equipped with ICT resources as well as knowledge on how to integrate ICT in their teaching. An interesting aspect from the findings was that despite being digital native themselves, the teachers struggled with incorporating ICT in their lessons. This was interesting because one would assume that given that the teachers are also born in the digital era, it would be easier for them to incorporate ICT in their teaching, moreover, that they would lean more towards ICT teaching methods as opposed to traditional methods. Tezci (2010) asserts that the success of ICT integration, in most part, lies in the teachers' technological knowledge as well as beliefs.

In line with incorporation of ICT in teaching of electric circuits. It was revealed by this study that the novice teachers did use ICT methods, however to a lesser extent. The teachers used online videos to explain difficult concepts. However, it was also observed that this was the only form of ICT method the teachers referred to, giving a unilateral view of ICT. Zungu (2022) posits that there are a range of ICT teaching methods (simulations, quizzes, educational games) that can be used to enhance science teaching. Perhaps there needs to be more research geared towards improving teachers' technological knowledge to improve the teaching and learning of science in general.

6.3 Factors that contribute to the challenges experienced by the Physical Science novice teachers

A number of factors were revealed to be contributing to the challenges experienced by the novice teacher**.** One of the factors was the lack of well-resourced facilities such as the laboratory. The teachers felt that they could not conduct practical activities due to this. In this regard, I argue that in such instances improvisation, using alternative resources should be considered. Furthermore, the teachers felt that that the lack of ICT resources limited their instruction to teacher-centred approaches such as question and answer. This study also found that the teaching approaches were influenced by the teachers' pre-service training as well as the teachers' high school experiences of the teaching of electric circuits. The teachers that hardly used practical tasks in their teaching also commented that they did not get proper training from their tertiary institutions regarding practical work, where Teacher 3 stated that "*I* *don't remember doing praticals for electric circuits in varsity and it is difficult to also find resources to do these practicals*". Naidoo (2012) posits that the teachers' schooling experiences shape their teacher identity.

One factor contributing to the conceptual challenges was the preparedness of the novice teachers to teach electricity. Most of the teachers felt that they were not adequately trained to teach electric circuits by the tertiary institutions. This was largely in relation to practical work. Most teachers come from a background where practical work is not effectively used as a tool for teaching and thus also do not consider the relevance of practical work in their teaching. Moreover, the tertiary institutions also do not put emphasis on equipping the pre-service teachers with practical work knowledge and skills. Additionally, teachers' beliefs also influence their use of practical work. Some teachers believe that practical work is time consuming as it requires preparations and immense classroom management skills as it is easy for learners to be disruptive during the lesson as they work in groups.

The exposure to practical work enables the conceptual understanding of electric circuits. Xongwana (2018) argues that in science learning, learners perform better when they are given an opportunity to be hands on with the concepts being taught. This also increases learners' ability to apply their knowledge in various settings, in this sense encouraging learners to be critical thinkers, as they engage as they explore concepts on their own guided by the teacher.

Furthermore, the teachers also indicated that they were not adequately prepared with the use of ICT in teaching electric circuits. As such, the teachers do not know how to incorporate practical tasks and ICT in their teaching. Moreover, the lack of resources was a contributing factor to the lack of practical activities in their lessons.

In my perspective, a contributing factor to the teachers' unpreparedness is that, even when practical activities are done at the tertiary institutions, it is with the use of specialized resources, e.g., electric circuits as opposed to using materials from every day experience. The use of resources from everyday life would show the teachers how to improvise in their schools, given that most schools lack resources. It is my belief that showing the teachers ways to improvise on resources would make practical task implantation easier for the learners.

Another possible reason for the teachers feeling unprepared for the teaching of electric circuits is that, tertiary institutions do not treat every topic in the curriculum during the four-year degree period and sometimes the pre-service teachers only experience the topic during teaching experience, even then, this is only for a few weeks. As a result, they only get a snapshot of the work experience. In this sense, most of the challenges become a reality once the pre-service teachers graduate and become full-time teachers. It is also important to highlight that it would be impractical to expect the tertiary institutions to treat every topic in the curriculum, however, more focus should be given to the topics that have been considered to be challenging by literature.

A factor that also contributed to the challenges, was the learners' everyday experiences and misconceptions. All the participants agreed that there were some misconceptions that persisted even after explanations, for instance, that charge finishes in the circuits. The learners' every day experiences of electricity also posed a problem to the understanding of electric circuits. The idea that electricity is 'finished' in the meter boxes contributes to the misconception that charge finishes in the circuit. In this case, the learners' prior knowledge hinders the teaching and learning of electric circuits.

Additionally, learners lacked mathematical skills and struggled with calculations of electric circuits. According to the teachers in this study, this lack of mathematical skills was as a result of learners relying on the internet for answers. It was found in this study that the teachers felt that the learners also did not put more effort and attention to understanding the concepts and calculations because they know they have easy access to the answers on the internet. Despite the schools having rules for the use of ICT in the classroom to control usage strictly for educational purposes as well as regulation on the uses of cell phones during school hours, however, due to the lack of ICT resources such as computers, the learners mostly watch the videos shared by the teacher through their cell phones. In this case it becomes difficult to monitor what learners are doing on their phones during the lesson. Moreover, in relation to homework, it also becomes difficult for the teacher to monitor whether or not the learners are engaging honestly with the activities or simply copying and pasting answers from the internet.

One major reason for the conceptual challenges was the learners' lack of interest in the topic of electric circuits. The lack of interest is a result of the abstract nature of electric circuits concepts and the teaching strategies used by the teachers. The rote learning approach makes learners passive in the classroom and given their low attention span they find the topic uninteresting. Furthermore, the learners' poor mathematical skills make the topic seem complex to understand. Boakye and Ampiah (2017) argue that learners often find topics that they feel are relatively challenging not interesting and thus participation from learners is limited in such topics.

The findings from this study show that the teachers acknowledge that the learners have a short attention span and often get bored during the lessons. However, it was found in this study, that the teachers hardly used ICT teaching methods in their lessons, despite being born in the technological era themselves. This was due to the lack of resources, lack of confidence in their abilities to use ICT, as well as a limited knowledge of ICT methods. Although the teachers seemed to use online videos to explain difficult concepts, however, their view of ICT methods were linear, and was only limited to online videos. Furthermore, the lack of ICT uses by the teachers was also as a result to the learner behaviours. The teachers felt that the learners were lazy and therefore would rely more on the internet instead of fully engaging with the concepts of electric circuits. Njoko (2018) argues that effective implementation of ICT in lessons could be used to make the teaching of science interesting and interactive.

6.4 How the physical science novice teachers address the challenges they experience

Findings from the interviews show that the teachers usually used videos and visuals in order to help learner understand a difficult topic. Teacher 3 indicated that they use a step-by-step explanation strategy with a combination of diagrams so that learners can have a visual picture of what he/she is explaining. One finding from the study indicating that ICT can be incorporated in science lessons was that, most teachers resorted to videos in order to explain a complex concept, for example, Teacher 1 stated that "*I enforce understanding through visiting external sources such as videos, where learners get the chance to visually see what is happening*". Furthermore, this aspect showed that that ICT was beneficial to improving the learners understanding of physical science. A study by Kotoko (2012) concurred with these findings.

With regards to the practical activities, the teachers stated that they go through the practical activities in the textbooks with the learners. However, in so doing the concepts of electricity still remain at an abstract level because the learners are not physically interacting with electric circuits in realistic situations. In terms of the lack of resources, the teachers agreed that they used alternative resources to teach the topic of electric circuit, however, these were not specified.

6.5 Limitations of the study

The study focused on the Johannesburg North district schools. The findings are limited to schools in the township and urban areas and therefore cannot be generalized beyond the scope of this study. Although the sample size allowed the researcher to identify challenges experienced by novice teachers, however, more could have been revealed by a larger sample, with the inclusion of schools from other districts. The COVID -19 pandemic also provided a limitation, as the interviews were conducted online. It would have been beneficial to have face-to-face interviews to further get in-depth information on the challenges.

6.6 Recommendations

This study explored the challenges experienced by physical sciences novice teachers. The reviewed literature in chapter 2, shows that there has been substantial research done on identifying the challenges faced by novice teachers generally, however, future research needs to focus on challenges unique to the current generation, how ICT can be incorporated in the teaching of science topics, given the momentum on the shift to the 4th industrial revolution as well as a shift towards dual instruction (contact and online lessons).

One factor influencing the challenges experienced by the novice teachers found in this study was that they felt not adequately prepared for teaching of electric circuits. This was mostly in relation to practical tasks. The tertiary institutions could consider reviewing their curriculum to incorporate more of practical activities to equip the preservice teachers with practical skills. The curriculum could look into equipping teachers with skills so that they are able to comfortably match schematic diagrams with their realistic circuits, deal with misconceptions related to charge in detail as well as more practice with mixed circuits especially the calculations related to the circuits as these were found to be difficult for both the teachers and learners in this study.

The findings from the study indicated that it is important for the novice teachers to be equipped with the knowledge and skills to effectively incorporate ICT in their lessons in the aim of catering to the current generation. Tertiary institutions need to tailor their programmes to accommodate the type of learners as well as teachers that occupy the classrooms today. Similarly, the Department of Education needs to ensure that it provides the teachers with skills as well as alternatives to making the science topics interesting in the absence of certain resources, for instance, workshops can be held were teachers from different schools share their teaching strategies.

These workshops are of utmost importance considering the fact that there are novice teachers who are digital immigrants and thus shy away from anything to do with ICT and thus could benefit from being exposed to ways on how to navigate through incorporating ICT in their lessons in the aim of benefitting the learners as digital natives. Moreover, the teachers should also involve themselves in personal self-development activities to improve their instruction on electric circuits. This can also be done at school level, where workshops are held and collaborative teaching and learning is encouraged. The department can provide incentives for such development programmes.

In addition, the schools should enforce stricter measures to ensure that learners take care of the school resources as well as encourage parents to monitor that that learners are keeping the textbooks in good condition to mitigate the challenges of lack of adequate textbooks.

6.7 Conclusions

All the participants in this study experienced challenges teaching electric circuits both contextually (Lack of resources) as well as conceptually (misconceptions, lack of mathematical skills, teacher-centred approaches). Furthermore, the teachers agreed that ICT methods were beneficial to teaching electric circuits however expressed their concerns with the ICT methods, such as that learners become uninterested in understanding concepts in the classes due to the easy access to the information online. All these findings indicate that the teacher training programs need to tailor their courses towards accommodating the current generation so as to better prepare the teachers in teaching generation Z learners.

6.9 Reflections

The study gave insights to the Johannesburg North District novice teachers experiences when teaching electric circuits in Grade 10. There are number of findings that emerged from this study. The study has revealed that the novice teachers experience challenges both contextually and conceptually when teaching electric circuits. Challenges experienced by the novice teachers were not exactly new, for example, the lack of resources, but have also been documented in other studies. In this study though it was the lack of specialized resources (laboratory equipment) that was most challenging as such limited the teachers' ability to do practical tasks. Secondly the novice teachers possess some content gaps and in turn perpetuate some misconceptions such as that, charge gets depleted in the electric circuit. lastly that the novice teachers have hesitations about incorporating ICT in their teaching of electric circuits despite agreeing that it would be beneficial to their teaching given the nature of learners as digital natives.

As mentioned above, the findings from this study are not new to educational research, however they are still significant towards literature aimed at improving instruction of electric circuits in the South African contexts. Moreover, the similarities in the challenges being identified to other research studies emphasis the areas of focus that need to be considered in improving the overall deliverance of the CAPS curriculum.

Through this study I also got to understand that some teachers do not have the correct conceptions of basic concepts such as current and voltage. These are considered the basic concepts and it is often assumed that teachers have a good understanding of these concepts. Being a novice teacher myself, these are the concepts that I too, take for granted given that they are introduced in Grade 9 and thus I work with the assumption that the learners already have an understanding of them.

The study also focused on the teachers experience with the incorporation of ICT in their teaching. It was evident that although some teachers used ICT methods, this was to a lesser extent. An interesting finding that the novice teachers had a limited knowledge of ICT teaching methods, despite being digital natives themselves. This was an interesting factor as one would assume that given that the teachers were born into the technologically advanced era then they would lean towards ICT teaching methods, moreover, that ICT incorporation would be much easier given that they engage with technology on a daily basis. Shockingly in relation to this, despite acknowledging that the learners found the topic of electric circuits not interesting the teachers mostly opted for the teacher centred approaches when teaching the topic. Perhaps the tertiary institutions should look more into teaching approaches that cater for the current generation and lessen the dominant focus on the content knowledge. Not to say that content knowledge is not important for teachers to know, however, in my perspective both content knowledge and pedagogical knowledge are equally important.

Moreover, given that most of the schools lacked specialized resources (laboratory equipment) perhaps the methodology courses in university should also consider teaching the pre-service teachers how to improvise with materials that are easily accessible. This study revealed that the novice teachers shy away from doing practical tasks with the learners because, firstly they do not know how to and secondly, they do not have the resources. It is my belief that most of the conceptual challenges faced by the teachers could be lessened by the doing of practical tasks, as the teachers and learners engage with the circuits realistically shifting the concepts towards a more concrete understanding.

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APPENDICES

APPENDIX 1

Interview Schedule

1.How long have you been teaching physical sciences Grade 10?	Biogeographical
2.What approach do you use when teaching concepts such as current, potential difference and resistance?	SQ2
3. Why do you think this is the best approach for teaching these concepts?	SQ2
4.Which concepts of electric circuits do your learners struggle with? Why do you think this is the case?	SQ1
5.What strategy do you use to explain a difficult concept?	SQ3
6.What kind of misconceptions from the learners have you picked up when teaching electric circuits Grade 10?	SQ2
7.Are there misconceptions that still persist even after explanation? How do you go about this?	SQ3
8.What has been your greatest challenge(s) in teaching electric circuits?	SQ1
9.What factors do you think contribute to the challenges you experience when teaching Electric circuits	SQ2
10.Do you think teaching the current generation (technology inclined), is any different to teaching the previous generations? Why?	SQ1
11.What difficulties, if any, have you encountered while teaching electric circuits to the current generation?	SQ1
12.What do you think is the possible reason for these difficulties?	SQ2
13.Seeing that the current generation is technology driven, do you think ICT can be incorporated in the teaching of electric circuits in Grade 10? If yes, how?	SQ3
14.Do you incorporate ICT in your teaching of electric circuits?	SQ2
15.Do you think incorporating ICT (e.g. simulations) could improve the understanding of concepts such as current and charge in electric circuits? Why?	SQ3
16.How have you attempted to resolve the challenges you experienced when teaching electric circuits to your grade 10 classes?	SQ3

APPENDIX 2

A Questionnaire for the Physical Science teachers

Instructions: Please mark with a cross on the appropriate answer.

SECTION A: Teacher Profile

1. **Gender** **Male** ☐ **Female** ☐

2. **Age group:** **18-25** ☐ **26-35** ☐ **36-45** ☐ **46- 55** ☐ **56+** ☐

3. **For how many years have you been teaching physical science grade 10**
   0-1 ☐ **2-3** ☐ **3-5** ☐

SECTION B: School Context

The area in which your school is located

Rural ☐ semi-rural ☐ township ☐ urban ☐

Does your school have the following resources? (Mark with a cross where appropriate)

Electricity	
Sufficient water	
Enough textbooks for learners	
library	
laboratory	
Enough laboratory equipment	
Other relevant teaching aids for science (science models, electric circuits etc.)	

SECTION C: Teachers' Experiences

Instruction: Please indicate your choice for the following questions, using the codes given below.

Strongly Disagree (SD)	Disagree (D)	Undecided (U)	Agree (A)	Strongly agree (SA)
1	2	3	4	5

The following questionnaire relates to your experience in teaching electric circuits at your school. Please tick ✓ in the box that best how far you agree or disagree with each item

QUESTION		SD	D	U	A	SA
		1	2	3	4	5
1.I experience challenges when teaching concepts such as potential difference, emf, current and resistance to Grade 10 learners	SQ1					

2.When teaching the topic of electric circuits, I often use investigations to help learners understand the concepts.	**SQ3**					
3.I do not have the resources to conduct investigations when teaching electric circuits	**SQ1**					
4.My learners are able to assemble circuits in series and in parallel.	**SQ1**					
5.My learners are able to interpret electric circuits and do calculations	**SQ2**					
6.My learners struggle with calculations in electric circuits	**SQ1**					
7. My learners are often able to relate the concepts of electric circuits to examples in everyday life	**SQ2**					
8.My learners struggle to make links between the concepts in electric circuits with real life situations	**SQ2**					
9.My teaching experience in university/ college adequately prepared me for teaching electric circuit	**SQ2**					
10.I have adequate resources for teaching electric circuits such as textbooks, electric circuits and other teaching aids	**SQ1**					
11.There are other alternatives I use when I run out of resources	**SQ3**					
12.The problem of resources affects my teaching of electric circuits	**SQ2**					
13.I use different teaching methods to make electric circuits interesting	**SQ3**					
14.My learners do not enjoy learning about electric circuits	**SQ1**					
15.I incorporate ICT when teaching electric circuits (videos, simulations, other online resources)	**SQ3**					
16. I only rely on the textbook when teaching electric circuits	**SQ2**					
17.I find that incorporating ICT in my lessons keeps the learners engaged	**SQ3**					
18. ICT is a distraction for learners in my classroom	**SQ2**					
19.When given tasks, my learners rely on their phones more than other resources such as textbooks	**SQ2**					
20.CAPS allocates enough time for the teaching and learning of electric circuits	**SQ1**					
21.I attend workshops to improve my teaching of electric circuits	**SQ3**					

22. I am able to resolve the challenges I face when teaching electric circuits to my Grade 10 class	**SQ3**					
23 I am often unable to resolve the challenges I face when teaching electric circuits	**SQ2**					

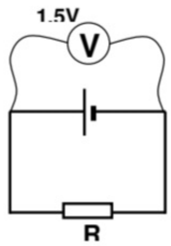
APPENDIX 3

Conceptual Challenges

1. Why do the light bulbs in your home come on instantaneously

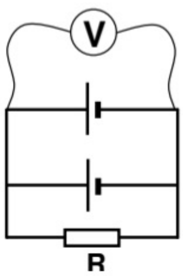
A	Charges are directly in the wire, when the circuit is completes, there is a rapid rearrangement of surface changes
B	Charge store energy. When the circuit is complete, energy is released
C	Charges in the wire travel very fast
D	The circuits in a home are connected in parallel. This means current is already flowing the wires

2. In the circuit below, a battery is connected to a resistor R. The voltmeter reads 1.5 V.



A second identical battery is now added, as shown below.

a) What is the reading on the voltmeter now?

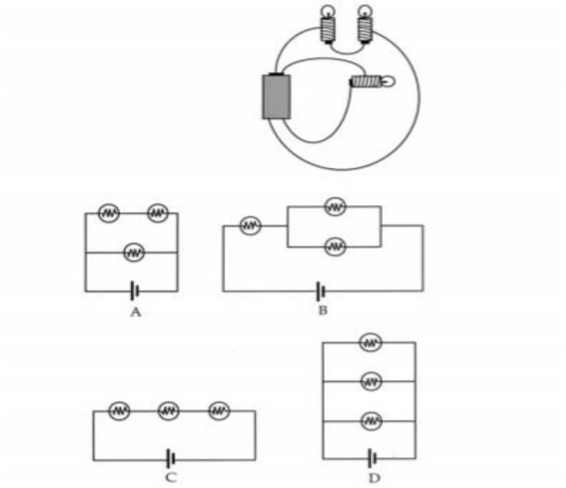


A	3V
B	1.5V
C	0.75V
D	0

b) How would you explain this?

A	Two batteries ‘push’ harder than one on its own
B	The voltmeter measures the potential difference across each battery
C	The second battery pushes against the first one
D	The two batteries transfer more energy to the resistor every second

3. Which schematic diagram best represents the realistic circuit shown below?



A. A
B. B
C. C
D. D
E. None of the above

4. A teacher explaining the flow of charge in a simple electric circuit uses the water analogy. He says that the flow of charge is like the flow of water in the water tank. The water is the charge, current is the flow of water, the pipes are the wires and the water tank is like the battery. When explaining voltage, the teacher says “think of the tank acting as a battery, where an amount of energy is stored and then released. The tank is placed at a certain height above the ground and a hose pipe is connected at the bottom of the hose. If we drain the tank, the pressure created at the end of the hose decreases. We can think of this as decreasing voltage, like when a flashlight gets dimmer when the battery runs down. This means there is a decrease in the amount of water that will flow through the hose. Meaning less water pressure means less water is flowing”.

a) One learner asks, “since the water in the tank decreases, does this mean that charge in the battery also gets finished”. How would you explain this concept to the learner?

APPENDIX 4: Interview transcripts sample

Sample of interview transcript for Teacher 1

Researcher: How long have you been teaching physical sciences Grade 10?

Teacher 1: I think it has been 3 years now. Since 2019 I think

Researcher: What approach do you use when teaching concepts such as current, potential difference and resistance?

Teacher 1: I do discussions where learners will express what they already know and believe about the concept of electricity, uhm… I then build up my lesson based on their knowledge and that time I infuse direct instruction approach, where I then teach them what is correct according to the concepts. Yah that's it.

Researcher: Why do you think this is the best approach for teaching these concepts?

Teacher 1: I think when you are teaching the kids, it is better to focus on the things that they need to know for the exam…like, uhm if you don't, they write other things in the test because they see their phones going battery low so they think it is same thing in the circuit.

Researcher: hmm, that is interesting… so now, which concepts of electric circuits do you feel your learners struggle with and also why do you think this is the case?

Teacher 1: my kids normally confuse potential difference and voltage. They can't differentiate between the two…umm, I don t know, but they think they are similar.

Researcher: How do you explain to them these concepts so that they understand?

Teacher 1: I draw the diagrams on the board, and explain slowly the difference between the two. Sometimes I give them examples from past papers so that the learners can see the difference.

Researcher: when teaching electric circuits what kind of misconceptions from the learners have you picked up.

Teachers 1: For example, when the electric meter box is out of token, they believe that there's no electricity and when they go buy tokens, they say that they bought electricity, so all these contribute to challenges when teaching the actual scientific concepts.

Researcher: how do you then try to correct the misconceptions

Teachers 1: I enforce understanding through visiting external sources such as online videos, where learners get the chance to visually see what is happening"

Researcher: okay…and are there misconceptions that persist even after explanation?

Teacher 1: Yes…like the one for charge finishing in the battery…I just go back to visuals and use real life examples to explain to the learners

Researchers: What has been your greatest challenge(s) in teaching electric circuits?

Teacher 1: getting the learners to do calculations in electric circuits. The kids can't do simple calculations and resources.

Researcher: can you please explain a little more about the resources?

Teacher 1: yes well, our school does not have that much resources, like ink to photocopy worksheets so we just use textbooks

Researcher: What factors do you think contribute to the challenges you experience when teaching Electric circuits.

Teacher 1: Not having enough resources to do practical with the learners.

Researcher: Why don't you have the resources?

Teacher 1: Most of the time the resources get stolen, sometimes the department promises to deliver them but they don't

Researcher: The learners we have in the classroom today, are technology driven, do you think teaching the current generation (technology inclined), is any different to teaching the previous generations? Why?

Teacher 1: Yes, there is a very big difference. They are technologically advanced, they love tv a lot so sometimes if you teach them something in class, you find that it's something that they already know compared to a generation that did not have phones, because everything that was said in class was theory to them. With these ones it is not only theory but is also practical

Researcher: That is interesting, so what difficulties, if any, have you encountered while teaching electric circuits to the current generation?

Teacher 1: They are very much outspoken; they think they know it all and their lack of discipline and also, they have as short attention span so they get bored very easily, especially during the long periods

Researcher: What do you think is the possible reason for these difficulties?

Teacher: I think it's because they know that they can get whatever they need from the internet so they don't not pay much attention in the class. Learners often just type in the question on the phone and copy and paste the answer in the book"

Researcher: Seeing that the current generation is technology driven, do you think ICT can be incorporated in the teaching of electric circuits in Grade 10? If yes, how?

Teacher 1: yes, it is very much possible. I think videos can be used to show the learners real electric circuits so that they understand better

Researcher: Do you incorporate ICT in your teaching of electric circuits?

Teacher 1: I do it when I see that they do not understand something, so I just go to online videos to refer.

Researcher: Do you think incorporating ICT (e.g., simulations) could improve the understanding of concepts such as current and charge in electric circuits? Why?

Teacher 1: Yes, because we have different types of learners, we have learners that learn by doing and those by watching. So, when you use ICT, you get the learners attention and learners will be willing to learn

Researcher: How have you attempted to resolve the challenges you experienced when teaching electric circuits to your grade 10 classes

Teacher 1: Normally when I run out of resources, I just tell the HOD to request whatever I need. Sometimes I get them sometimes I don't.

Sample of interview transcript for Teacher 2

Teacher 2

Researchers: How long have you been teaching physical sciences Grade 10?

Teacher 2: started in 2020, so 2 years.

Researcher: What approach do you use when teaching concepts such as current, potential difference and resistance?

Teacher 2: I normally just use the question-and-answer approach, and also explanation of the information the kids need to know.

Researcher: Why do you think this is the best approach for teaching these concepts?

Teacher 1: I think when you are teaching the kids, it is better to focus on the things that they need to know for the exam…if you don't, they write other things in the test.

Researcher: hmm, that is interesting…. Which concepts of electric circuits do you feel your learners struggle with? Why do you think this is the case?

Teacher 2: My *learners struggle with understanding potential difference and voltage, because they are similar so they can't differentiate between the two*

Researcher: How do you explain to them these concepts so that they understand?

Teacher 2: I just use step by step analysis. First, I will find out what is it that the learners do not understand, then I draw the circuit on the board to explain the learners, step by step how the current will flow, which branches does it divide and remains the same. same things apply with voltage this helps them to understand easily

Researcher: when teaching electric circuits what kind of misconceptions from the learners have you picked up.

Teacher 2: Learners think that direction of conventional flow is from the negative terminal of the battery towards positive terminal, where as it flows from positive to negative

Researchers: What has been your greatest challenge(s) in teaching electric circuits?

Teacher 2: Finding the total resistance for mixed resistors connection and mixed connections in general

Researcher: how do you then try to correct the misconceptions

Teacher 2: *I use videos and bring visual pictures to show learners what I am explaining.*

Researcher: okay. And are there misconceptions that persist even after explanation

Teacher 2: I think for me it has to be misconceptions and resources. it is difficult make the kids understand that current does not finish in the circuit, especially since the phones they use always need to be charged

Researcher: can you please explain a little more about the resources?

Teacher 2: *most of the textbooks we have are damaged, because the kids do not handle them properly, so every year we have books missing pages…*

Researcher: What factors do you think contribute to the challenges you experience when teaching Electric circuits.

Teacher 2: The learners are not serious about their studies because they do not want to study and always want to be spoon fed everything

Sample of interview transcript for Teacher 3

Teacher 3

Researchers: How long have you been teaching physical sciences Grade 10?

Teacher 3: probably 4 years

Researcher: What approach do you use when teaching concepts such as current, potential difference and resistance?

Teacher 3: *I first introduce the concepts by explaining what they mean and then I use drawings on the board to explain the concepts in relation to the parallel and series circuits*

Researcher: Why do you think this is the best approach for teaching these concepts?

Teacher 3: I think when I use drawing to explain the topic, it makes it easier for the learners to remember in the exam.

Researcher: hmm, that is interesting…. Which concepts of electric circuits do you feel your learners struggle with? Why do you think this is the case?

Teacher 3: *Finding effective resistance for resistors connected in a combined or mixed network*

Researcher: How do you explain to them these concepts so that they understand?

Teacher 3: sometimes I ask one of the bright learners to explain the concept to her peers, so that they get a different explanation that may make them understand

Researcher: when teaching electric circuits what kind of misconceptions from the learners have you picked up.

Teacher 3: *When there is a labelled 1.5V, they think 1.5V is in the external circuits and it's so hard for them to believe the concept of internal resistance that decreases the emf of the cell.:*

Researchers: What has been your greatest challenge(s) in teaching electric circuits?

Teacher 3: I think for me it has to be teaching the learners the different circuits, like identifying branches where the current divides or stays the same

Researcher: how do you then try to correct the misconceptions

Teacher 3: *I come with my laptop and show them videos or just hotspot them so they can watch the videos on their phones*

Researcher: okay. And are there misconceptions that persist even after explanation

Sample of interview transcript for Teacher 4

Teacher 4

Researchers: How long have you been teaching physical sciences Grade 10?

Teacher 4: I started last year July

Researcher: What approach do you use when teaching concepts such as current, potential difference and resistance?

Teacher 4: I explain the important information and then give the learners questions to practice what they have learnt.

Researcher: Why do you think this is the best approach for teaching these concepts?

Teacher 4: My facilitator always encourages us to stick to the important things that learners need for the exam. So that is why is just explain what the learners need to know.

Researcher: hmm, that is interesting…. Which concepts of electric circuits do you feel your learners struggle with? Why do you think this is the case?

Teacher 4: *The learners struggle to identify the branches of the circuit where potential difference is the same and where it divides, likewise with current flow*

Researcher: How do you explain to them these concepts so that they understand?

Teacher 4: I use diagrams and drawing to explain the concepts, so that learners see what I am talking about

Researcher: when teaching electric circuits what kind of misconceptions from the learners have you picked up.

Teacher 4: *Learners always think that when the bulbs are not brightly lit when the switch is on, it means that electricity in the circuit is finishing*

Sample of interview transcript for Teacher 5

Teacher 5

Researchers: How long have you been teaching physical sciences Grade 10?

Teacher 5: 3 years

Researcher: What approach do you use when teaching concepts such as current, potential difference and resistance?

Teacher 5: *I use question and answer and the narrative approach*

Researcher: Why do you think this is the best approach for teaching these concepts?

Teacher 5: the question and answer show me if the learners are understanding what I am saying or not and the narrative approach allows me to explain the topic to the learners

Researcher: hmm, that is interesting…. Which concepts of electric circuits do you feel your learners struggle with? Why do you think this is the case?

Teacher 5: The kids, do not understand current fully, especially when it comes to charge. They think that charge will finish in the circuit

Researcher: How do you explain to them these concepts so that they understand?

Teacher 5: re-explain the concepts using simple language, because sometimes it's the big words that confuse the learners in

Researcher: when teaching electric circuits what kind of misconceptions from the learners have you picked up.

Teacher 5: one misconception that the learners have is that the more batteries you add in a circuit, the bigger the voltage regardless of whether it is a parallel or series connection.

Researchers: What has been your greatest challenge(s) in teaching electric circuits?

Teacher 5: I would like to do practicals with the learners but I can't because we do not have the material. This is one of my big challenges

Researcher: how do you then try to correct the misconceptions

Teacher 5: if I can...I use a mini demonstration to show learners a real electric circuit and use it to explain the concept

Researcher: okay. And are there misconceptions that persist even after explanation

Appendix 5: Sample of coded interview transcript

Teacher 1: getting the learners to do calculations in electric circuits. The kids cant do simple calculations → Calculations being problematic (factor)

Researcher: how do you then try to correct the misconceptions

Teachers 1: I enforce understanding through visiting external sources such as online videos, where learners get the chance to visually see what is happening → ICT incorporation → for explaining difficult concepts

Researcher: okay…and are there misconceptions that persist even after explanation

misconceptions (charge) →

Teacher 1: Yes!..like the one for charge finishing in the battery…I just go back to visuals and use real life examples to explain to the learners

Researcher: can you please explain a little more about the resources? → contextual challenges

Teacher 1: yes well, our school does not have that much resources…ink… → lack of resources

Researcher: What factors do you think contribute to the challenges you experience when teaching Electric circuits. Factors → lack of resources

Teacher 1: Not having enough resources to do practical with the learners.

Researcher: The learners we have in the classroom today, are technology driven, do you think teaching the current generation (technology inclined), is any different to teaching the previous generations? Why? → Pros - of ICT incorporation

Teacher 1: Yes, there is a very big difference. They are technologically advanced, they love tv a lot so sometimes if you teach them something ~~in class,~~ you find that its something that they already know compared to a generation that did not have phones, because everything that was said in class was theory to them. With these ones it is not only theory but is is also practical → electricity more practical than before.

Researcher: that is interesting, so what difficulties, if any, have you encountered while teaching electric circuits to the current generation?

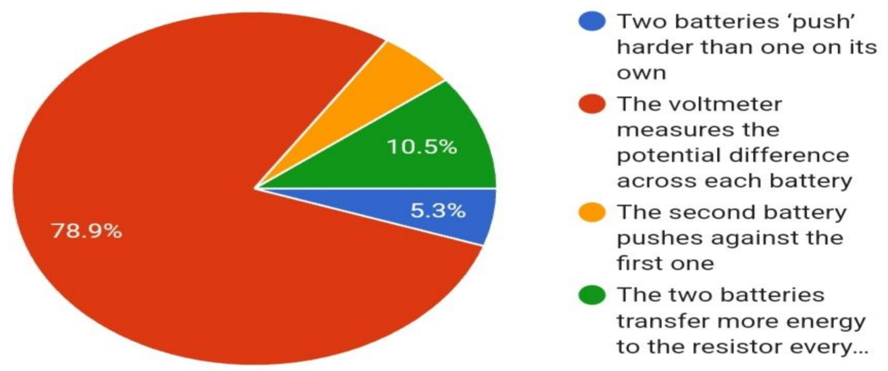
Teacher 1: they are much outspoken; they think they know it all and their lack of discipline.

Researcher: What do you think is the possible reason for these difficulties? → Cons of ICT

Teacher: I think its because they know that they can get whatever they need from the internet so they don't not pay much attention in the class . → low attention span → Interest in the topic of electricity

Perhaps also linked to teacher approaches

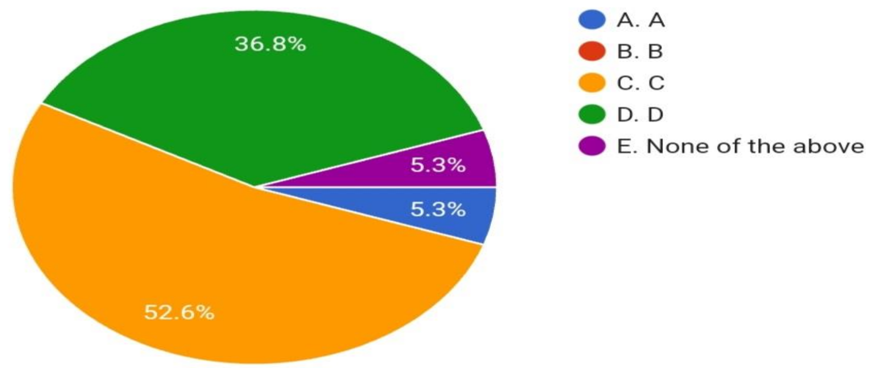
APPENDIX 6: Sample of questionnaire responses



Copy

3. Which schematic diagram best represents the realistic circuit shown below?

19 responses



APPENDIX 7: Information Letter for Teachers and Consent Form

Information Letter for Teachers and Consent Form

Dear Sir / Madam

My name is Hlayisani Tracy Nkuna and I am a Masters student in Science Education at the University of the Witwatersrand in Johannesburg. I am conducting research on the **Challenges Experienced by Physical Sciences Novice Teachers when teaching Electric circuits in Grade 10 Science Classrooms**.

The research project intends to understand the challenges physical sciences teachers experience when teaching electric circuits Grade 10 and the factors that contribute to these challenges,

As part of this project I would like to invite you to take part in the interviews and answering a questionnaire regarding your experiences teaching Grade 10 electric circuits. The data collection involves Two web-based questionnaires and will be completed at a time and place convenient to you.

and will take place after school hours. The questionnaire will be filled electronically, to comply with the Covid regulations. With your permission, the interviews will be audio recorded, transcribed and analyzed after the sessions. The project also involves interviewing you based on your general experiences with teaching electric circuits in Grade 10. The interview will also be done through online means after school hours.

You will not be advantaged or receive benefits in any way and there are no disadvantages or penalties for not participating. You may withdraw at any time. Your identity will be kept confidential throughout the study and also in my final research report. The information you give to me will be kept securely in my password encrypted laptop and used strictly for academic writing and no other purposes. All the research information will be destroyed after 3-5 years of the project completion.

You are welcome to contact me If you have any questions at any time about this research, feel free to contact me. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email Shaun.Schoeman@wits.ac.za

Yours Sincerely

Ms. Hlayisani Tracy Nkuna

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Hlayisani Tracy Nkuna, 1147317@students.wits.ac.za, 0721501403

Supervisor:

Dr. Emmanuel Mushayikwa, emmanuel.mushayikwa@wits.ac.za,

Teacher's Consent Form

Kindly fill in the form below by circling your response

I………………………………consent to my participation in this project. The researcher has explained to me all the necessary details of the study and I understand what my participation entails.

I agree to the following:

	Circle one
To be interviewed for this study	Yes/ No
I am aware that I can withdraw at any time and don't have to answer	Yes/No
Any question I am uncomfortable with	Yes/No
I agree to be audiotaped during the interview	Yes/No
I am aware the audiotapes will be used for this project only	Yes/No
I agree to participate in answering the questionnaire	Yes/No

Sign……………………………………………. Date………………………………….

APPENDIX 8: Ethics Clearance letter

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG | WSoE Wits School of Education

SCHOOL OF EDUCATION ETHICS COMMITTEE

CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: 2022ECE023M**
PROJECT TITLE	An Investigation of Challenges Experienced by Physical Sciences Novice Teachers when teaching Electric circuits in Grade 10 Science Classrooms: A case of three Johannesburg North District Schools
INVESTIGATOR	Nkuna Hlayisani Tracy
SCHOOL/DEPARTMENT OF INVESTIGATOR	WSoE
DATE CONSIDERED	24 June 2022
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	LOW RISK
EXPIRY DATE	Date of submission of the Research Report
ISSUE DATE OF CERTIFICATE	**CHAIRPERSON** Mbokane Dr. Batseba Mofolo-Mbokane

cc: Dr. Dr Emmanuel Mushayikwa

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

I fully understand the conditions under which I am are authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

tnkuna

Signature **Date** 12 / 07 / 2022

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