AN EXPLORATION OF GRADE 7 TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE WHEN TEACHING ELECTRIC CIRCUITS AT LOWER UMVOTI CIRCUIT OF THE ILEMBE DISTRICT OF KWAZULU-NATAL

BY

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ABSTRACT

This study offered insight into the teachers' Topic Specific Pedagogical Content Knowledge (TSPCK) when teaching electric circuits. There was a need of conducting this study to ascertain the grade 7 teachers’ TSPCK since the researcher is responsible for supporting the teachers when teaching electric circuits. In addition, the research in this regard is limited. The TSPCK involves changing what is taught to a form that could be comprehended by the learners at topic level. The study focused on TSPCK and electric circuits as a topic since this topic is regarded as difficult and abstract, hence it was anticipated that the teachers benefitted from this study. The researcher also benefited from the study in terms of understanding the teachers’ TSPCK when teaching electric circuits.

The research questions for this study read: What is the level of grade 7 teachers’ content knowledge when teaching electric circuits? What is the nature of grade 7 teachers’ topic specific pedagogical content knowledge when teaching electric circuits? What is the correlation between grade 7 teachers’ content knowledge and topic specific pedagogical content knowledge when teaching electric circuits? The first research question assisted in capturing the teachers’ content knowledge (CK) of electric circuits. The second research question helped in capturing teachers’ TSPCK when teaching electric circuits. The third question aided in ascertaining the correlation between TSPCK and CK when teaching electric circuits.

The paradigm that was employed in this study is pragmatic paradigm. A pragmatic paradigm was used in this research because it was a mixed methods approach. Qualitative and qualitative methods are employed to comprehend the problem and to answer the research questions. In this study, the teachers’ experiences and views involving their knowledge were taken into cognisance to understand their TSPCK.

The study involved multiple case studies that focused on the teachers’ TSPCK when teaching electric circuits. The case studies were used for comparing and getting insight into the teacher’s TSPCK. A sample of four teachers was used to collect data.

Data collection employed a mixed methods approach in which the qualitative and quantitative data were collected. The convergent method was used since quantitative and qualitative data were collected independently, and the results were compared.

TSPCK data were collected using a TSPCK assessment tool questionnaire, and CK data were collected using a CK assessment tool questionnaire. The questions on a TSPCK questionnaire were aligned to categories, including learner prior knowledge and misconceptions; curriculum saliency, difficult ideas to teach in electric circuits, representations, conceptual teaching strategies of electric circuits, learners' diversity for inclusive teaching of electric circuits, technologies for teaching electric circuits, various contexts in which teaching electric circuits takes place, assessing electric circuits and teaching resources for electric circuits. These categories were intended to ascertain the teachers' TSPCK when teaching electric circuits. These categories became the themes of this study. The rubric was used to rate qualitatively TSPCK questionnaires' responses. The questions in the CK assessment tool were linked to misconceptions and intended to ascertain the teachers misunderstanding when teaching electric circuits. The memorandum was used to score CK assessment tool questions.

Data analysis involved analysing TSPCK and CK assessment tools qualitatively and quantitatively independently. CK and TSPCK data were compared using the Pearson moment correlation and regression correlation.

The results revealed that the teachers' TSPCK is developing and CK is at level 2. The relationship between CK and TSPCK is a positive weak relationship, which means TSPCK predict CK even though the relationship is weak.

The gaps and good practices were identified. The study recommended that workshops should be conducted to capacitate the teachers with regards to electric circuits. This study also contributes to the literature considering teachers' TSPCK when teaching electric circuits in grade 7.

DECLARATION

I Millicent Khanyile, declare that “An exploration of the grade 7 teachers’ topic specific pedagogical content knowledge when teaching electric circuits at Lower Umvoti circuit of the Ilembe district of Kwazulu-Natal**”** is my work and the resources that are used were denoted and acknowledged as references.

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Researcher: Millicent Khanyile

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Supervisor: Mr M.P Moodley

ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

01 August 2022

Millicent Khanyile (992251712)
School of Education
Edgewood Campus

Dear M Khanyile,

Protocol reference number: HSSREC/00004178/2022
Project title: An exploration of the grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits at Lower Umvoti circuit of the Ilembe district of Kwazulu-Natal
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 11 May 2022 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 04 August 2023.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/ms

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INSPIRING GREATNESS

DEDICATION

I dedicate this thesis to my brother, Zakhele Khanyile, who passed away in 2021.

ACKNOWLEDGEMENTS

I would like to thank God for being with me during this difficult journey of my research study. God granted me resilience since I lost four family members during the period of my study.

Also, I would like to thank the following people who contributed to this study:

Mr. M.P Moodley (my supervisor) for providing me with support, motivation guidance and advice that made it possible for me to finish this research study.

Mrs. B.P Mabaso for the support, guidance, and motivation to forge ahead when I was discouraged.

The teachers who participated in this study irrespective of their busy schedules.

ABBREVIATIONS

CAPS: Curriculum and Assessment Policy Statement

CoRes: Content Representations

ICT: Information and Communication Technologies

EAC: English Across the Curriculum

PCK: Pedagogical Content Knowledge

PHET: Physical Education Technology

TSPCK: Topic Specific Pedagogical Content Knowledge

BED: Bachelor of Education

CHAPTER ONE

1.1 Project title

An Exploration of the Grade 7 Teachers' Topic Specific Pedagogical Content Knowledge when Teaching Electric Circuits at Lower Umvoti Circuit of the Ilembe District of Kwazulu-Natal.

1.2 Introduction

This case study explored grade 7 Technology teachers' TSPCK when teaching electric circuits at lower Umvoti Circuit of the Ilembe district in KwaZulu -Natal province.

Technology is still viewed as a new subject hence it does not have adequate research. Martin and Ritz (2013) reiterate that its literature is limited nationally and internationally. Therefore, this study might contribute to addressing the gap of limited literature regarding grade 7 teachers' TSPCK when teaching electric circuits.

There are different studies related to TSPCK in the South African context, whilst searching through literature I could not find the study that explored grade 7 teacher's TSPCK when teaching electric circuits. The TSPCK studies focused on different issues for instance a study by (Makhechane & Mavhunga, 2021) focuses on comparison of TSPCK at level of planning to teach between preservice teachers and final year traditional Bachelor of Education (BED) preservice teachers, this study outlined the development of a rubric to portray the quality of enacted TSPCK in classroom teaching. Mavhunga & Miheso (20210) 's study outlines the development of a rubric to portray the quality of enacted Topic Specific Pedagogical Content Knowledge (TSPCK) in classroom teaching. Another study focused on changes in pre-service teachers' planned TSPCK in stoichiometry topic (Malcolm & Ndlovu, 2022). Most studies did not involve TSPCK of grade 7 Technology teachers. This study took note of this deficiency hence focusing on TSPCK. The researcher's work involves supporting the teachers when teaching electric circuits. Hence there was a need for conducting this study to understand their TSPCK, content knowledge and it was envisaged that this study could contribute to Technology literature since it is limited. The good practices and gaps in teachers' TSPCK were identified to improve the teaching of electric circuits.

Therefore, the purpose of this study was to explore the teachers' TSPCK when teaching electric circuits. The participants were four grade 7 Lower Umvoti Technology teachers. The study was conducted using the questionnaire of CK assessment tool and the TSPCK assessment tool questionnaire. The participants accessed and submitted the questionnaires using WhatsApp.

Chapter 1 covers the project title, introduction, problem statement, purpose of the study, objectives, critical questions, significance of the study, location of the study, limitations, conclusion, summary of methodology and the preview of the chapters to follow.

1.3 Problem statement

There is limited research in Technology as a subject. This is also reiterated by (Mapotse, 2014) in a study. The other studies also confirm this notion. According to (Martin & Ritz, 2013), some Technology studies propose research regarding the understanding of pedagogical content knowledge (specialised pedagogical content knowledge for technology education). This study therefore identified a gap since the PCK is not topic specific. This is the evidence of limited literature of TSPCK in Technology when teaching electrical circuits.

When comparing Technology to other subjects or topics, various studies involving TSPCK were conducted including the study conducted by (Mafa-Theledi et al., 2020) covering market dynamics, focusing on the TSPCK involving the interaction of the content and representations only. The study that was conducted by (Mavhunga, 2015) focused on natural interactions between the components of TSPCK and pointed out the teaching context in which they arise.

Electric circuits were selected as the topic in this study because what is happening in electric circuits is abstract and that makes this topic challenging for teachers and learners. This is posited in the study that was conducted by (Zimmerman, 2015) focusing on electric circuits. It is further indicated that TSPCK is a good topic to establish how teachers transform knowledge for teaching since it is not only the learners that have misconceptions with regards to electric circuit content, but even the teachers do have misconceptions. This indicates that even the teachers might be holding misconceptions, and this highlights the degree of difficulty of the topic.

The gaps in teachers' TSPCK when teaching electric circuits and the related teacher development programmes are identified to enhance teaching. It was also anticipated that the study would also contribute to Technology research. According to (Mavhunga & Rollnick, 2013), professional programmes should develop PCK at topic level (TSPCK) since it involves a conceptual understanding of its components and their relationship.

This study was motivated by (Zimmerman, 2015)'s study focusing on electricity topic and measurement of TSPCK, as well as (Mavhunga & Rollnick, 2014)'s study focusing on content knowledge and TSPCK and the topic being electrochemistry. This study explored grade 7 Technology teachers' TSPCK focusing on the topic of electric circuits.

1.4 Purpose of the study

The purpose of this case study was to explore the grade 7 Technology teachers' TSPCK when teaching electric circuits in Lower Umvoti Circuit of the Ilembe district in KwaZulu Natal province. The study sought to get better insight into the teachers' TSPCK when teaching electric circuits. This was interpreted considering the teachers' practices and their different views and reflections related to the experiences of the participants. It was envisaged that it would lead to improved teaching of electric circuits by informing future teacher development programmes. In this study, TSPCK is defined as the transformation of content knowledge to teachable form considering the specific topic as stated by (Mavhunga, 2015; Mavhunga & Rollnick, 2014). In this study, the TSPCK topic is electric circuits.

1.5 Objectives

The objectives of this study were:

- To explore the level of grade 7 teachers' content knowledge when teaching electric circuits.
- To explore the nature of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits.
- To establish the correlation between grade 7 teachers' content knowledge and topic specific pedagogical content knowledge when teaching electric circuits.

1.6 Critical questions

1. What is the level of grade 7 teachers' content knowledge when teaching electric circuits?
2. What is the nature of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits?
3. What is the correlation between grade 7 teachers' content knowledge and topic specific pedagogical content knowledge when teaching electric circuits?

1.7 Significance of the study

The study was significant because it provided an understanding of teachers' TSPCK when teaching electric circuits. It was envisaged that the study would inform future teacher development programmes that would be identified to mitigate the challenges. It was anticipated that the learners' performance would also improve if the teacher's performance is enhanced.

This study contributed to Technology subject literature since there is limited literature. It was anticipated that it would also align the Technology subject to the literature of other subjects or research topics as far as research trends are concerned. The researcher's practice improved since the areas that needed special attention and the good practices were identified. The teachers might benefit from the study by improving their performance when teaching electric circuits.

1.8 Location of the study

The study involved four Technology grade 7 teachers from four rural schools in Lower Umvoti Circuit in KwaZulu Natal province. The Circuit is in the Maphumulo geographical area of Ilembe District. The area is characterised by poverty but politically stable. The schools that were selected for the study are primary schools. It was envisaged that these schools needed extra curriculum support to improve the performance of learners in the subject. Since the country was experiencing Covid-19, adherence to safety measures was mandatory. In this study, CK and TSPCK assessment tools questionnaires were used to collect data via WhatsApp due to Covid-19 restrictions.

1.9 Limitations

According to plan, the study was supposed to have eight participants, but four participants declined, hence four participants participated. Initially, the research was based on the interview and class observation as tools to collect data. The plan had to change the CK, and TSPCK assessment tools questionnaires were used to capture data. WhatsApp was utilised to send and submit the TSPCK and CK assessment tools questionnaires since it was difficult to visit the schools due to Covid-19. The teachers were apprised over the phone with regards to receipt and submitting the questionnaires. Technology literature is limited hence the literature for this study was also sourced from other subjects or topics within the South African and other countries' curricula.

1.10 Conclusion

For this study, it was important to get insight into Technology as a subject before further exploration of TSPCK. Technology is a new subject involving skills, values and knowledge considering the learners' environment and community to meet the needs and wants of the society. Many teachers are not qualified to teach the subject. However, it was also important to conduct a study involving experienced teachers to identify the gaps and mitigate the challenges they experience. There is limited literature with regards to TSPCK related to teaching electric circuits topic, hence this study could contribute to the literature, as well as determine the areas that need improvement when teaching electric circuits.

1.11 Summary of methodology

This study employed the mixed methods approach since it was exploratory as stated by (Cresswell & Cresswell, 2018). This study explored grade 7 teachers' TSPCK. The study collected data via WhatsApp using CK and TSPCK assessment tools questionnaires since there was a risk of Covid-19.

1.12 Preview of chapters to follow

Chapter two of this study includes the introduction; literature review focusing on Technology subject, teaching, Pedagogical content knowledge, TSPCK, theoretical framework, pragmatic framework, teacher development programmes, and content representations. The literature review enabled the researcher to get an understanding of TSPCK as the researcher explored grade 7 Technology teachers' TSPCK.

Chapter 3 covers the introduction, research paradigm, research design including research methodology, strategy of inquiry, sampling and sampling methods, data collection as well as reliability, validity, credibility, confirmability, transferability, dependability, flexibility, and ethical considerations. Chapter four covers introduction, data analysis overview, analysis, findings, matters of concern and conclusion. Chapter five covers introduction, discussion of findings and interpretation (according to research questions), summary of findings, recommendations, future research, and conclusion.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter covers the following: Introduction, Technology (overview of Technology as curriculum subject that is taught in grade 7), teaching, PCK, TSPCK, content representations (CoRes), paradigm (pragmatic paradigm), teacher development programmes and conclusion.

It is important to get insight into Technology as a subject before delving much into this study. An understanding of the previous studies related to test instruments; PCK; TSPCK and CoRes offer the foundational knowledge of how teaching was measured or studied. The pragmatic paradigms provide a philosophical perspective of this study. The gaps that are identified in other studies provide insight related to TSPCK at the level of electric circuits and the recommendations to enhance teaching.

2.2 Technology as a subject in the curriculum.

This study included Technology as subject that is taught in South African curriculum. The reason for including it is to provide the background with regards to what is taught in terms of the content covering electric circuits, to ascertain gaps existing in literature related to TSPCK and electric circuits as well as to clarify how Technology term is used in the context of this study. Sometimes there is a misunderstanding as far as this Technology term is concerned. Gumbo (2018) affirms this notion by focusing on misconception and misrepresentation in Technology because it is mistaken with Engineering Education, Educational Technology, Science Education and Technical Vocational and training. Mabaso (2014) concurs by pointing out that the misinterpretation might inhibit the implementation and development of the subject.

Hlatshwayo et al. (2022) posit that there are arguments regarding the term Technology in various countries, as some perceive it as a teaching resource and some as a subject as is the case in South Africa, it is taught in primary schools. In this study, Technology is perceived as a subject that is taught in South African schools in grade 7.

It is significant to get an insight into what is entailed in Technology. According to (Heymans, 2007), Technology encompasses the utilisation of resources, skills, and knowledge to fulfil the needs and wants. This is congruent with what is stipulated by Curriculum and Assessment Policy Statement (CAPS) (Education, 2011b) in the South African context as Technology involves the skills, values and knowledge considering the learners' environment and the community to meet the needs and wants of society. Barak and Hacker (2017) regard Technology Education as human changing a natural world to address the needs. Technology is knowledge, and resources available are utilised in the environment and community to cater for its needs, ensuring sustainable development. Doyle et al. (2017), Gumbo (2018) and Rolph (1997) stated that Technology is practice, results and scientific engineering research. The students develop ideas and technological solutions cooperatively, and the activities involve practical problem solving as pointed out by (Svensson & Johansen, 2017).

It is evident that Technology involves knowledge, skills and values that are required in life by the people; it deals with the needs of the people; it considers the available resources; it takes cognisance of social factors and the environment.

Teachers teach the knowledge related to electric circuits though some teachers are qualified to teach Technology, and some are not. Nonetheless, the study focused on experienced teachers, meaning the teachers have taught electric circuits, their TSPCK and content knowledge was explored taking cognisance of electric circuits that are taught in Technology subject.

According to CAPS (Education, 2011b), Technology prepares the learners for further grades and studies. Hlatshwayo et al. (2022) also indicate that Technology allows learners to choose careers related to engineering at high school and university levels. It is also the mandate of the Department of Basic education to increase access to these Technology subjects in the Further Education and training (FET) as stipulated in the medium term strategic framework 2019-2024 (Education, 2019) and Action Plan to 2024 (Education, 2020). This indicates that if the teachers have sound knowledge of the electric circuits, they can teach the electrical circuits, and they will be able to contribute to the realisation of these mandates as well as equip the learners for future courses and careers that involve electric circuits.

However, Technology in South Africa is still regarded as a new subject in the past decade as articulated by (Doyle et al., 2019) since it was not a formal subject in South Africa before Curriculum 2005 implementation (Heymans, 2007). Even in New Zealand, it was introduced and associated with science subjects before it was taught as a stand-alone subject in 1994

(Fahrman et al., 2015). This indicates that Technology is still new and is having limited literature. This study continuously referred to studies that were conducted by scholars in other subjects or fields due to limited literature. There are limited frameworks from Technology studies, hence even (Doyle et al., 2019) highlighted the need for a Technology conceptual framework.

Some scholars recommended studies to be conducted in Technology, for instance, pedagogical development of teachers (Boz & Şimşek, 2016) and PCK (Depaepe et al., 2015). On the other hand, the current studies recommend PCK at the level of the topic (TSPCK). Gumede (2020) articulates that there are few studies from the South African perspective that studied the teaching and learning of electric circuits. This resonates with Technology since it is difficult to get South African studies involving electric circuits. According to the above views, it is evident that studies should be conducted to contribute to a Technology framework instead of relying on other subjects.

Like many areas of the curricula internationally, Technology education has encountered difficulties in achieving continuity between what is depicted in policy and curricular documents and the actuality of everyday practices (Doyle et al., 2019). Various scholars hold this sentiment. Mapotse (2014) affirms that by positing that some teachers are not qualified to teach Technology education, hence they do not teach with confidence. This is also maintained by (Fahrman et al., 2015) when pointing out the challenges in Technology, including insufficient training of Technology teachers which results in teachers teaching differently by focusing on what they were trained on. The same sentiment is shared by (Heymans, 2007) when articulating that when Technology was introduced, the educators were not prepared, and they had to teach a subject they were not familiar with. This implies that when Technology was introduced, some teachers lacked the necessary knowledge of the subject. This indicates that the knowledge that the teacher possesses makes it easy or difficult to teach Technology due to a lack of alignment with what is in the policy, curriculum documents and the teachers' practices.

Unqualified teachers might be tempted to teach what they are comfortable with and omit some important concepts with which they are not well acquainted. It can also lead to teachers conveying their misconceptions to the learners when they teach some concepts like electric circuits. Therefore, this study focuses on experienced teachers teaching Technology as a subject, focusing on electric circuits to understand their TSPCK. Fahrman et al. (2019) considered conducting the study involving experienced teachers.

In conclusion, anecdotal evidence suggests that there is a shortage of qualified teachers. Even if the teacher is qualified to teach, it might happen that they are not comfortable teaching some aspects of the curriculum. Teachers need support in this subject. This study involving the understanding of the grade 7 teachers' TSPCK will play an important role in understanding their knowledge when they teach electric circuits to identify gaps and recommend the programmes that can assist them to improve their practices.

2.3 Teaching

Shulman (1987) states that teaching starts with the teacher knowing what should be learnt, how to teach, what is correct and what is wrong in theory and practice. Loke et al. (2015) have drawn from the work of Shulman, 1986 and stated that the content is about what is known, and pedagogy involves how to teach.

This means since the teachers teach electric circuits in Technology, they should be able to identify incorrect perceptions or answers, aspects that create confusion to the learners and what is supposed to be taught as stipulated by CAPS at various levels of the curriculum. According to (Shulman, 1987), teaching involves the understanding by the teacher of what is taught, as well as the link of ideas that exists within the subject and other subjects.

In conclusion, this section shows the importance of the knowledge of the teacher to transform subject matter to teachable form. To do that, the teacher should have sound knowledge of the content and pedagogy. In this study, the teacher should know what to teach in electric circuits, how to teach electric circuits and how to transform electric circuit subject matter to teachable form.

2.4 Pedagogical content knowledge (PCK)

The tests and class observations were used to study teaching, although there were shortcomings, including the lack of subject matter or content dimensions, hence PCK was initiated by (Shulman, 1986). This indicates that the initial instruments that were used had a limitation of the vital part in teaching, which is subject matter, hence the studies shifted to the use of PCK.

The different scholars defined and explained PCK differently. Andrews and Auerbach (2018) assert that there are arguments regarding PCK’s conceptualisation. Brückmann et al. (2017) indicate that there is no consensus regarding the meaning of PCK.   Abdulla and Halim (2010) concur by stating that PCK is rationalized differently. Häkkinen et al. (2019) argue that the PCK is not a separate field, and this notion is also denoted by other scholars. This shows the unanimity regarding how PCK is viewed, since it could be defined and explained differently, and it could be treated as a unit or not. Gaiger and Moodley (2017) indicate that PCK is not one unit, but it is all kinds of knowledge, including how the subject is taught. These claims show that PCK should not only be studied as a separate subject/discipline, since it encompasses various types of knowledge even how the subject is taught.

Shulman (1986) defines PCK as the teachers’ explanations and transformation of the subject matter knowledge to expedite student learning which is significant to understand teaching and learning. The teachers should process subject matter by interpreting it so that it is easily understood by learners. Barnet and Friedrichsen (2015) define the PCK as the process of changing the subject matter to be understood by the learner.

This implies that PCK is how the teacher changes the subject matter in a way that the learners could grasp, which is vital for teaching and learning. Mavhunga and Rollnick (2017) define PCK as a significant hidden knowledge of content teaching that the teachers have without realising it. This indicates that the teacher's PCK is abstract. Callingham et al. (2016) add the knowledge of the context of the school when defining it. This means PCK is abstract, and it has a direct bearing on teaching and learning. Teachers cannot teach the subject matter without making it teachable by considering context, pedagogy and content since pedagogy and content are enacted at the same time for the students to understand the subject matter. Hence, in addition to knowledge of conceptions and misconceptions, the teacher must know context and teaching strategies. PCK involves the subject specific teaching strategies, knowledge and explanations and students’ conceptions and misconceptions (Baumert et al., 2014), including knowledge of instructional strategy (Demirdo¨g˘en, 2016).

It is evident that PCK consists of pedagogy and content, and this implies that it involves what should be known by the learner and how to impart what should be known by the learners. This indicates that PCK contributes to professional learning and involves the knowledge of subject matter and understanding related to the way the student learns and the context of the school.

The teachers are either experienced or inexperienced. The teaching practice (Bjo ̈rkholm & Hulte´n, 2015) and the teachers’ experiences are significant for their PCK development (Chan & Yung, 2017). They concluded that the teaching practices of experienced teachers present useful information about the future development of teachers and future teacher education and professional development courses. This indicated that it is vital to conduct studies on PCK since previous studies did not focus on experienced teachers. These studies offer beneficial information with regards to education for the teachers and professional development because what the teachers encounter when they teach is playing an important role in enhancing teaching. This means PCK played a significant role in the studies of teaching.

Different scholars point out the significance of the PCK and its shortfalls. The importance of PCK has been maintained by different scholars, including (Abdulla & Halim, 2010) when pointing out the importance of PCK for teaching any discipline. PCK is significant for research considering Technology development and research trends (Williams, 2015). This shows that Technology researchers can continue conducting PCK studies as indicated by the research trends. This is also emphasised by (Alama ̈ki, 2017) when reiterating that more research needs to be conducted to understand deeply the knowledge dimensions. As much as PCK is having advantages, however, PCK is having its shortfall.

Different studies point out PCK deficiency as it is generic and not aligned to a specific topic. Some scholars argue that the general PCK does not point out the competency specific to each topic and that results in teachers finding it difficult to teach a specific topic (Mafa-Theledi et al., 2020). Mavhunga and Rollnick (2017) argue that initially it was difficult to define PCK and provide examples, yet it is not difficult to define it at topic level.

As much as the PCK could be used to study teaching, currently some studies still argue its usefulness, and this study identified its shortfall. PCK is vague since it does not take into consideration the topic. It was improper to employ PCK in this study because it considered PCK at the topic level (TSPCK). O'Brien (2017**)** articulates that TSPCK is the basis on which the subject matter at a topic level is conveyed to the learners.

PCK studies contributed to changing what is learnt into teachable form. However, there is a shift from conducting PCK studies due to its shortfall. PCK is not aligned with a topic, and this resulted in the emergence of studies focusing on PCK at the level of the topic (TSPCK). Mavhunga and Rollnick (2014) posit that the PCK is employed to a particular topic. This was a shift from the view of PCK as a distinct field to TSPCK.

In conclusion, initially, the PCK framework was developed by Lee Shulman in1986, and TSPCK emanated from it. It is therefore relevant to understand PCK before delving much into TSPCK.

2.5 Topic Specific Pedagogical Content Knowledge

TSPCK derives from PCK. According to (Mavhunga, 2015; Mavhunga & Rollnick, 2014), TSPCK refers to the transformation of content knowledge in a certain topic into teachable form. TSPCK also involves the relationship of content knowledge and TSPCK (Mavhunga & Rollnick, 2013). This implies that content knowledge could also be studied with TSPCK since these are related.

This means TSPCK is a form in which the subject matter is imparted to the learners depending on the knowledge of the teacher. Mavhunga and van der Merwe (2020) state that through TSPCK, the teachers shift from knowing what is supposed to be taught to knowing how to impart what the teacher knows about the content. This is evident if the teacher is teaching.

Mbono (2019) posits that TSPCK is evident if the teacher structures and changes the content knowledge for teaching a particular topic. This implies that if the teachers teach electric circuits, they convert those concepts into the form that could be comprehended by the learners. This can contribute to the improvement of learner attainment. TSPCK is therefore suitable for this study since it involves what to teach and the actual process of cascading what is taught to make it easy for the learners to understand.

Different studies focused on different topics. Davidowits and Potgieter (2016) conducted a study focusing on the teachers' TSPCK. Different TSPCK studies that were conducted focused on different topics, for instance, electrochemistry (Mavhunga & Rollnick, 2014), chemical equilibrium (Mavhunga & Rollnick, 2013), stoichiometry (Mavhunga et al., 2019), electric circuits (Zimmerman, 2015), chemistry (Mavhunga & Miheso, 2021), redox and electrochemistry (O'Brien, 2017) and practicum (Akin et al., 2014).

These studies show the shift from general PCK to TSPCK; hence this study focuses on TSPCK of the teachers when teaching electric circuits. The choice of the topic of electric circuits was inspired by the study that was conducted by (Zimmerman, 2015). This topic was chosen because the teachers teach electric circuits in the South African curriculum as stated by (Education, 2011b). Zimmerman (2015) states that electric circuits are abstract and not easy to teach. This shows that electric circuits are complicated to teach since what is happening in an electric circuit is abstract. In addition, good teaching entails the ability to reason with regards to teaching (Mavhunga & Rollnick, 2014). The learners have to think and make electric circuits. The teacher is therefore required to make electric circuits easy, hence it is significant to understand TSPCK in this regard.

Zimmerman (2015) articulates that TSPCK is a good topic to establish how teachers transform knowledge for teaching, since it is not only the learners that have misconceptions with regards to electric circuit content, but even the teachers do have misconceptions. Mavhunga and Rollnick (2014) concur with this assertion by stating that TSPCK takes cognisance of a specific topic and misconceptions as learners' pre-knowledge. Since TSPCK takes cognisance of the topic, hence if it is fully developed, the teacher could alleviate the learners' misconception, for instance, in electric circuits.

The content knowledge of the teachers could not be ascertained at a glance, and TSPCK highlights the knowledge of a topic that is possessed by the teacher. When teachers teach, they change this content knowledge into teachable form, and the interaction of content knowledge and TSPCK occurs. Chen and Park (2012) propose that PCK at the level of the topic (TSPCK) entails the relationship of various components of it. It was clear that the study exploring the teachers' TSPCK when teaching electric circuits was needed. It was envisaged that it would provide clarity with regards to how the teachers teach electric circuits, the interactions that occur regarding TPCK components and content knowledge identified that would answer the research questions related to the level of CK, the nature of TSPCK and the correlation between CK and TSPCK.

In conclusion, TSPCK involves changing what is learnt into teachable form at the level of the subject. This study also focused on the relationship that exists between teachers' content knowledge and TSPCK components when teachers teach electric circuits that are abstract. This would provide a picture of how the enactment is carried out and the challenges would be identified, with relevant interventions recommended. To accomplish this, a TSPCK framework is needed from which the conceptual framework emanates.

2.6 Theoretical framework

In early studies, a PCK framework was used by different scholars to understand teaching. According to (Mavhunga & Rollnick, 2017), some early studies are aligned with the PCK framework. Different frameworks are used by different scholars to study TSPCK. Carlson and Daehler (2019) point out the model used to establish specialised professional knowledge involving the domains collective PCK, personal PCK, and enacted PCK. As this study explored the teachers' TSPCK when teaching electric circuits, it was vital to understand the different frameworks of PCK before engaging in TSPCK frameworks since TSPCK emanated from the PCK framework.

To understand how teachers transform knowledge to teachable form, initially the PCK framework was developed by (Shulman, 1986), and it included different knowledge domains, including content knowledge (knowledge of the subject matter representation), understanding of student subject conception, general pedagogic knowledge and knowledge of the curriculum and educational knowledge context. The framework makes PCK clear.

Shulman (1987) posits that for teachers to be efficient, they need to possess seven knowledge bases, including content knowledge, general pedagogical knowledge, curriculum knowledge, PCK, knowledge of learners and their characteristics, knowledge of educational context and knowledge of educational ends, purposes and values and their philosophical and historical grounds.

Comparing the framework that was developed by (Shulman, 1986) and the framework developed by (Shulman, 1987) it added to the domain of knowledge of educational ends, purposes and values and their philosophical and historical grounds. This study looked at PCK from which the TSPCK emanates.

Shulman (1999) in (Abdulla & Halim, 2010) states that PCK consists of overlapping knowledge domains, including content knowledge, context knowledge and pedagogical knowledge. Gess-Newsome regards teaching as an act emanating from incorporating knowledge among these three domains (Abdulla & Halim, 2010).

Later, different studies adopted Shulman's framework when exploring learning and teaching. These frameworks include the framework that was developed by (Khoza, 2016) comprising knowledge of subject matter, general pedagogic knowledge, knowledge of the students and knowledge of context.

In a study of Technology by (Lockley & Williams, 2012), they regard the PCK model that was developed by (Borko, et al., 1999) as useful in studying the teachers' professional knowledge and reiterate that the PCK for experienced teachers involves orientations towards teaching, knowledge of curriculum, knowledge of assessment, knowledge of understanding of the subject by the student and knowledge of instructional strategies.

This framework was also adapted by (Fahrman et al., 2019) by modifying the Science knowledge domains to Technology education domains, including orientation towards teaching Technology, knowledge of the Technology curriculum, knowledge of pupils' understanding of Technology, knowledge of instructional strategies for teaching Technology and knowledge of assessment in Technology.

Although some studies still employ PCK when studying teaching in Technology, according to (Fahrman et al., 2019), there is a shift from PCK to TSPCK framework when studying the explanations and transformation of the content knowledge to teachable form at topic level. Since PCK is not linked to a topic, that makes it irrelevant for a study like this that focuses on electric circuits topic. Some scholars argue that the general PCK does not focus on competency specific to each topic and that results in difficulty when teachers teach a specific topic (Mafa-Theledi et al., 2020). This indicates that the framework that is chosen in this study should accommodate PCK at topic level (TSPCK).

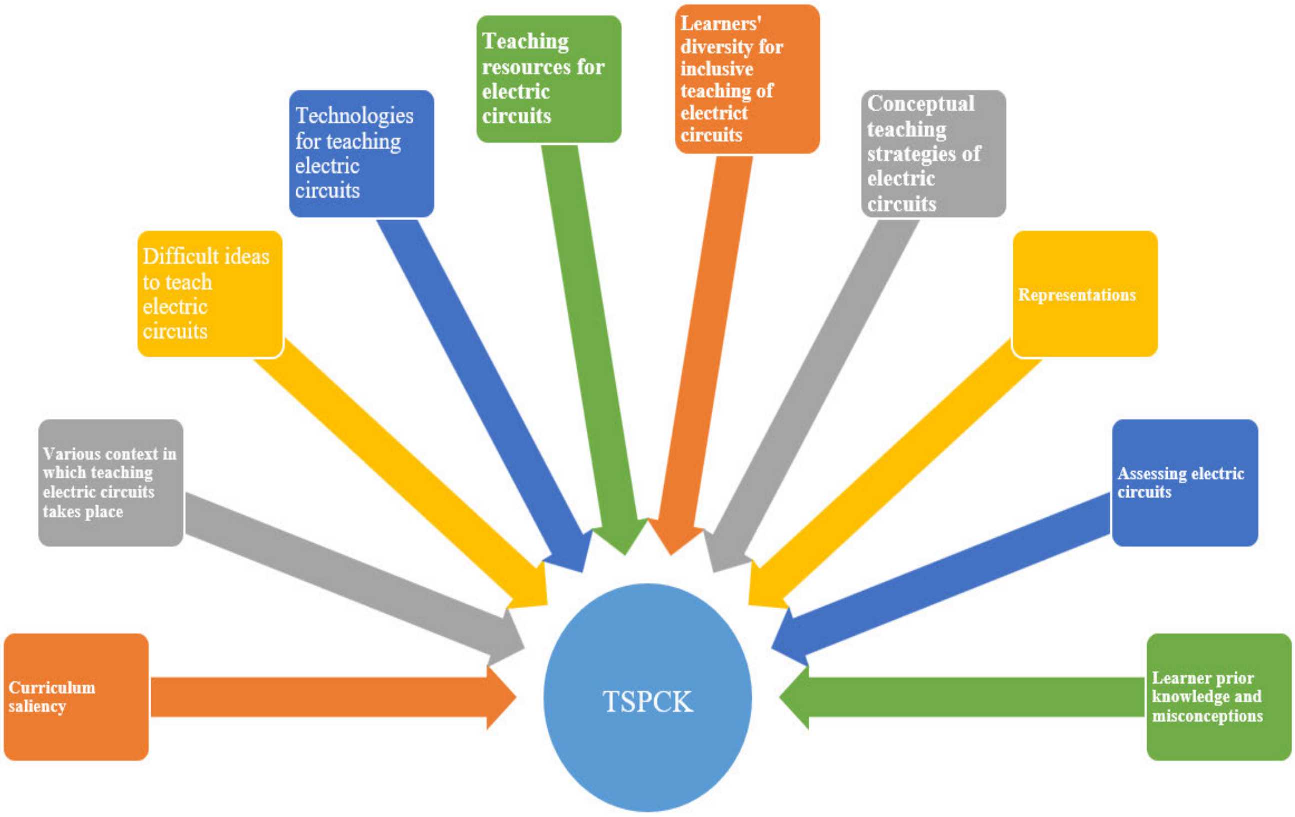
Different scholars use different frameworks to study TSPCK. In a study that was conducted by (Mavhunga & Rollnick, 2013), the components of a TSPCK framework included the learner's prior knowledge, curriculum saliency, what makes a topic easy or difficult to understand, representation including analogies and conceptual teaching strategies. This study employed this theoretical framework to develop the conceptual framework. This framework was also used in studies that were conducted by (O'Brien, 2017), as well as (Zimmerman, 2015).

Azam (2019) highlights TSPCK components including TSPCK of student learning, TSPCK of the Science curriculum, TSPCK of goal of science teaching, TSPCK of assessing science learning, TSPCK of instructional strategies, TSPCK of Science teaching resources, TSPCK of technologies for science teaching, TSPCK of student diversity for inclusive science education and TSPCK in various contexts.

This study identified the shortcomings of the PCK framework that was initiated by (Shulman, 1986), which is not topic specific, and the framework that was developed by (Mavhunga & Rollnick, 2013). According to White Paper 7 (Education, 2004), schools should use technology when teaching and learning take place; these frameworks do not incorporate technology. The White Paper 6 (Education, 2001) promotes inclusivity in teaching and learning, but in both frameworks, it is not evident as well as assessment. To address these shortcomings, this study employed the theoretical framework by (Mavhunga & Rollnick, 2013) and topic specific pedagogical content knowledge components as articulated in (Azam, 2019) and (Zimmerman, 2015).The rationale for adapting this framework is to include the component that are not captured by the TSPCK framework (Mavhunga & Rollnick, 2013).

This study used the adopted conceptual framework emanating from the theoretical framework by (Mavhunga & Rollnick, 2013) and TSPCK components echoed in studies that were conducted by (Azam et al., 2019) and (Zimmerman, 2015) respectively. The conceptual framework for this study is illustrated in Figure 2.6. It includes learner prior knowledge and misconceptions, curriculum saliency, difficult ideas to teach in electric circuits, representations, conceptual understanding of electric circuits (Zimmerman, 2015; Mavhunga &Rollnick, 2013), learners' diversity for inclusive teaching of electric circuits, technologies for teaching electric circuits, various contexts in which teaching electric circuits takes place, assessing electric circuits and teaching resources for electric circuits (Azam et al., 2019). The rationale for adapting this framework is to include the component that are not captured by the TSPCK framework (Mavhunga & Rollnick, 2013). The researcher is responsible for supporting the teachers in those components.

Figure 2.6 Illustration of adapted TSPCK conceptual framework from (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015)



2.6. 1 TSPCK components

The adapted conceptual framework in Figure 2.6 was employed in this study, and this section elaborates on the components of TSPCK.

2.6.1.1 Category: Curriculum saliency

Curriculum saliency is one of the components of TSPCK. Mbono (2019) points out that curriculum saliency is the knowledge of the teachers pertaining to how the topics of the curriculum are arranged or ordered and the place of each topic and its purpose in the curriculum. In addition, (Young, 2013) regards curriculum as the form of specialised educational knowledge that is necessary to enhance learning opportunities and improve the curriculum. In this study, curriculum saliency involves knowledge of the arrangement of topics or concepts of electric circuits which enhances the curriculum and the link of different concepts. The teacher should know the integration in electric circuits topics. Demirdo¨g˘en (2016) stipulated that teacher should have a sound knowledge of the curriculum topics that link with each other and the ones that link across the grades.

The learners should understand some concepts. Technology CAPS document (Education, 2011b) stipulates electric circuits concepts that should be taught, and they are regarded as difficult. This topic is taught in Term 3. The teachers are expected to have this knowledge, as well as the knowledge of what is taught in grade 6 as the foundation for grade 7.

Grade 6 simple electrical circuits include the source of energy (battery or cell), conducting wire, switch, light bulb, buzzer, motor, the complete unbroken circuit, broken pathway for electricity and circuit diagrams (Education, 2011a). Önder et al. (2017) claim that direct current circuits, short circuits and open circuits are of significance since they form the foundation of the understanding by the student of electric circuits. Handhika et al. (2017) reiterates that a simple circuit is made up of one or more batteries, lamps and short wires and the students should comprehend the concept of open circuit, electric current and resistance.

Grade 7 electrical circuits also link to the topics in grade 10-12 Physical Sciences, for instance, principles of electricity. These electric circuits equip the learners for the topics of electronics in grade 9 Technology (Education, 2011b) and grade 10 Electrical Technology Education (Education, 2014). In grade 7, the electric circuits are linked to the specific aim, and the annual teaching plan for Technology includes electric circuits that are supposed to be taught. As the teacher teaches considering the policy of the curriculum, TSPCK and content play a key role, hence the teacher should know different categories of TSPCK. In this study, the teacher's knowledge of the learners is captured in the category of learner prior knowledge and misconception.

2.6.1.2 Category: Learner prior knowledge and misconception

Besides the knowledge of curriculum saliency, the teacher should have the knowledge of learner prior knowledge (existing knowledge before learning what is new) and misconceptions (what is incorrect or not complete), which is the components of TSPCK. Handhika et al. (2017) argue that errors could be made when analysing electric circuits without clear knowledge of concepts hence (Carlson & Daehler, 2019) points out that knowledge of students influences pedagogical reasoning of the teacher pertaining to teaching.

The teachers need to know the learners' misconceptions and prior knowledge since they come to class with some concepts of which are incorrect. Misconception means a wrong view that results from flawed thinking (Gumede, 2020). The knowledge they come with to class serves as the basis for the new knowledge that is taught could be right or wrong. Hence the teacher should know misconceptions. Soysal's 2018 study asserts the need for learning certain science concepts and the misconceptions and alternative conceptions that the students (learners) have.

Demirdo¨g˘en (2016) posits that teachers must know about Science learning and student's misconception (learner's misconceptions). Majengwa (2010) states that misconception also plays a vital role in learning since they blend with new knowledge but sometimes, they are the reasons for errors. On the other hand, (Gumede, 2020) argues that the emphasis on alternative conceptions can only lead to the understanding of the learners' difficulties, and it does not consider the teaching and learning strategies that are based on research that will enable the leaners to understand a topic. This study perceived misconceptions as significant in building new concepts and how to teach to alleviate these misconceptions.

Different scholars identify misconceptions in electric circuits, for instance, static electricity; electric power; electric potential and work, direct current circuits; electric field (Önder et al., 2017); circuit consumes the current and the battery is a constant current source (Engelhardt, 1997). The prior knowledge and misconceptions were considered in this study.

It is evident that the prior knowledge of the learners plays a vital role in making connections with the new knowledge. The teachers need to know the prior knowledge of the learners because that will enable them to identify alternative conceptions that the learners bring to class. Teachers should be able to spot the misconceptions and should not allow the misconceptions to be developed concurrently with the new knowledge. The misconceptions should be corrected as soon as they arise. Any teacher who does not know the misconceptions will not be able to rectify them. Therefore, teachers should have the knowledge of prior knowledge and misconceptions that the learners bring to class to assist the learners develop the correct concepts of electric circuits.

2.6.1.3 Category: Difficult ideas to teach electric circuits

Teachers should know difficult ideas to teach when teaching the learners electric circuits since the electric circuits are abstract. Marks (2012) highlights some ideas that could be difficult when teaching electric circuits, including the impact of the current, the flowing charges in wires; forming mental imagination of resistance; controlling the current jointly with the battery, potential differences. In addition to that (Dewati et al., 2019) mention the electrical voltage, electric resistance, direct current law, calculating power, electrical energy in series and parallel DC electrical circuits. In this study, teachers were required to indicate these difficult ideas to teach.

The abstract concepts may not be known by the learner and that will result in difficulty with regards to understanding that particular concept (Education, 2013). It means that if the learner does not have prior knowledge of a concept, which will lead to a lack of understanding of that particular concept, and this necessitates the strategy that needs to be used by the teacher to make that concept easy to be understood by that learner. This strategy can involve the representations to make abstract concepts visible.

2.6.1.4 Category: Representations

As much as the knowledge of learner prior knowledge and misconception is required, the teacher should also know representations. These representations assist the learners in understanding difficult concepts. Representations are those depictions of concepts that are utilised by the teachers to assist them when teaching a certain topic (Mbono, 2019). This implies that during teaching, text only is not enough to teach the concepts but the other methods are used to supplement text to make easy what is taught.

Different types of representations can make some concepts easy when teaching. The different scholars provide examples of representations, including demonstrations, illustrations, metaphors, simulations, examples, explanations and analogies (Shulman, 1987); models, games, examples, drawn structures and concept maps (Mbono, 2019); textbooks (to develop deeper learning) with an inadequate number of analogies (Jonāne, 2015); verbal representation and schematic circuit diagrams using the standardised electrical components symbols (e.g. straight lines and right angles signifying the wires) (Lombard & Simayi, 2019); mental models (Borges & Gilbert, 1999), illustrations, simulations, examples, models analogies and metaphors (Fahrman et al., 2019).

The material that is presented by the teachers should be relatable to the learners (Gumede, 2020). If the teachers teach, they should know different representations to enhance learning and teaching. The representations should create a conducive learning and teaching environment, and they should be relevant to that particular topic in the case of this study which was electric circuits.

Analogies are examples of representations that play a vital role in the understanding of concepts. Analogies are pedagogical tools that relate ideas, things, or processes to another that is not the same but works the same, and they clarify difficult concepts that are difficult to understand.

Analogies make abstract concepts to be comprehended by the students; they reinforce understanding and may cause misconceptions (Jonāne, 2015). Handhika et al. (2017) concurs by positing that the concept electrical is an abstract concept, hence it becomes difficult for the learners to understand due to their restricted knowledge. This implies that the analogies clarify abstract concepts and can help learners visualise electrical concepts. However, analogies should be used with caution since they may perpetuate misconceptions. Therefore, the teacher should have knowledge of using analogies.

Different scholars make examples of analogies that are related to electric circuits. According to the research, students experience challenges when it comes to series and parallel circuits, and they relate the diagrams as systems of pipes through which the water flows (Engelhardt, 1997); water is related to electricity, for instance, electric current flows and water flows in pipes (Jonāne, 2015).

Lombard and Simayi (2019) suggest that when learners are taught the circuits, the starting point should be the concrete visual representation (pictorial representation) with familiar objects, followed by making circuit drawings thus schematic representations to the circuit diagram. This emphasizes the importance of starting with the concrete visual representations, for instance, the assembled electric circuits serve as concrete visual representation.

The knowledge of instructional strategy necessitates that the teachers understand and use subject specific argumentation and topic specific representation (analogies, models and graphs) instructional strategies (Demirdo¨g˘en, 2016). This indicates that teachers should know the teaching strategies or instructions to use the representations efficiently.

2.6.1.5 Category: Conceptual teaching strategies

Shulman (1987) states that instruction is a visible teaching act, and it involves features of pedagogy like classroom organisation and management; offering explanations and clear descriptions; allocating and verifying work; using questions and probes to communicate efficiently with the students, answers and reactions and praise and criticism. This means that teaching strategies serve as a vehicle through which the teacher explains, describes, distributes work, and communicate by posing questions during teaching.

Different scholars highlight the way teaching should take place. Mbono (2019) reiterates that when teachers teach concepts, they must use role play like games about a particular concept; in collaborative learning, learners are involved in acting a part played by a particular concept, or making an object in clay in a fun environment. Mbono (2019) shares that planned practical work to be done regularly, including lectures, demonstrations, recitations or seatworks, explanations and discussions. Teaching strategies in TSPCK denote the teachers' knowledge of appropriate teaching strategies that are employed when teaching a certain topic to address alternative conceptions and the difficulties that the learners have.

Handhika et al. (2017) states that if the concepts and conceptions of the students are not correct, that necessitates the teacher to select the relevant learning model or strategies to stimulate students understanding of the concepts. It is significant for the teacher to have the knowledge of the conceptual teaching strategies of a certain topic to correct alternative conceptions and to make easy the concepts that the learners find difficult.

It is important for the teacher to consider some factors that influence the choice of the teachning strategy when teaching a certain topic. The instructional strategies are influenced by the teachers' knowledge, class size and content that is expected to be taught (Mbono, 2019). Soysal

(2018) points out that in Science, strategies are specific to teaching since they could be implemented in certain topics. The instruction considers particular subject matter conceptions and ideas that the learners already know before they learn a concept about what is electricity and how electricity works since it could not be seen (de Jong & Koll€offel, 2013).

When the teachers teach electric circuits, the knowledge of instructional strategies for electric circuit concepts is required for effective teaching of these concepts. The knowledge of instruction will contribute positively when the teacher selects the instructions to teach these concepts.

2.6.1.6 Category: Assessing electric circuits

Different scholars argue that the knowledge of assessment includes the knowledge of the concepts to be assessed and the knowledge of the ways that are used to assess those concepts.

Demirdo¨g˘en (2016) states that the knowledge of assessment involves the knowledge of the teacher about what to assess(concepts) and how to assess (concept maps or open-ended questions).

According to (Education, 2011b), assessment is the process that is ongoing of collecting and interpreting information with regards to the learner's performance by employing different forms of assessment. The feedback is provided to the learners frequently, and it informs planning for teaching. Jones and Moreland (2004) highlight that the teacher's feedback skills should be developed. It shows that the teacher should have knowledge of feedback.

Assessment could be formal or informal (Education, 2011b). Fahrman et al. (2019) also concur by articulating that assessment in Technology involves knowledge about formative and summative assessments. Assessment can be done formally and informally, and the teacher ascertains whether the lesson is attaining the learning outcomes of a particular topic or not (Gumaelius et al., 2014).

Informal assessment allows teachers to discover the topic or concept that needs more attention, the concept in which the learners experience difficulties. This could allow instant intervention before the learners are engaged in formal assessment. According to (Education, 2011b), examples of informal assessment include observation, discussions, practical demonstration, learner-teacher conferences and informal classroom interactions. Learners or teachers mark these tasks.

Education (2011b) reveals that formal assessment tasks are marked, recorded, and are used for progression purposes. These tasks provide an understanding of whether the methodology and strategy achieved what is intended or not. The examples include practical assessment tasks and tests. The electric circuits are assessed formally during Terms 3.

Naidoo (2013) states that if teachers are having inadequate Technology pedagogical knowledge and knowledge of appropriate assessment strategies, they end up paying more attention to products rather than lifelong learning and achievements. Gumaelius et al. (2014) concur by indicating that untrained teachers' knowledge of assessment is limited, resulting in unfair and unequal assessment. They also point out that teachers should be supported in Technology assessment to ensure reliability and validity.

Formative assessment relies on knowledgeable assessors that can act on the interpretation of observation and student outcomes to improve learning, and various strategies should be employed (Jones & Moreland, 2004).

Considering what has been pointed out in the literature, it is evident that teachers should know assessment with regards to what should be assessed, how assessment should be conducted, forms of assessment and how and when to provide feedback. The teacher should know formative and summative assessment and how to assess formally and informally. Besides knowledge of assessment, knowledge of technology, is required when teaching is taking place, hence teacher development is required.

2.6.1.7 Category: Technology for teaching electric circuits.

According to the White Paper on e-Learning (Education, 2004), information and communication technologies (ICT) should be employed to enhance learning and teaching and for employability and productivity. Moreover, it promotes deep learning, comprehension, reasoning, problem solving and creative thinking. It is therefore necessary for teachers to implement ICT in the classroom and have the knowledge of ICT to enhance teaching and learning.

The studies have revealed that ICTs have contributed to better learner attainment (Education, 2004). An example of real-life knowledge is demonstrated in simulation when teaching electric circuits. The simulations involve the models that imitate the actual system, process or phenomenon that could be used instead of actual equipment of electricity and simple electric circuits, and it allows the student to manipulate the variables (de Jong & Koll€offel, 2013). They further make examples of simulations, including virtual electrical circuits and voltage or current where students undertake experiments and obtain data without any difficulty.

ICTs could be used to provide instant feedback to the learners like quizzes and assignments. Computers can give feedback to students if their responses to assignments are incorrect (de Jong & Koll€offel, 2013). Videos can also be used to clarify difficult concepts with regards to electric circuits. Teachers should work on finding learners' misconceptions and expose learners to the best internet videos to gain more information about the concepts (Mbono, 2019).

ICT plays a vital role in stimulating the learners' interest which results in better understanding, reasoning, problem solving and creative thinking. This implies that if ICT is implemented in the classroom, the learners' understanding of electric circuits will be enhanced considering its abstract nature and that will improve the learner achievement in these concepts. It will also encourage the learners to engage meaningfully in electric circuit activities involving simulations, quizzes, games, animation, videos, and assignments. It is therefore of significance for the teacher to be acquainted with ICT for the teachers to be able to implement ICT when they use and create the content, informal and formal tasks that are relevant to electric circuits.

2.6.1.8 Category: Learner diversity for inclusive teaching of electric circuits

According to CAPS (Education, 2011b), inclusivity plays an important role in teaching if the teachers are knowledgeable with regards to learning barriers and planning for diversity. White Paper 6 (Education, 2001) stipulates that the learning needs of the learners emanate from an inflexible curriculum, language of teaching and learning, a lack of teaching methods and resources that are required to mitigate the learning barriers. According to the guidelines for inclusive teaching and learning (Education, 2010), one of the barriers that is identified is the language and communication barrier. It is emphasised that when the learner's barrier is the language of learning which is not their home language, the teachers should provide additional support in the language of learning and teaching (Education, 2001).

If the learner is having a barrier, then that obstacle should be attended to in the classroom. (Education, 2011b). This implies that if the learner is experiencing a barrier, for instance, in electric circuits because of English as a medium of instruction, it is not the responsibility of the English teacher only to assist the learner in mastering the language of instruction. It becomes the responsibility of the Technology teacher too to support the learners in developing their English proficiency to learn electric circuits meaningfully.

Various curriculum differentiation strategies are used by the teachers, including the strategies that are related to technological knowledge and understanding as stipulated in the guideline for inclusive learning (Education, 2013). These strategies include teaching particular meanings of all terms, talking learners through the concepts and ideas, being mindful of various meanings of terms, using visual cues and flashcards with pictures. This emphasises the use of different strategies to accommodate inclusivity.

The performance of learners is also associated with the language of teaching and learning (Education, 2013) and the Department of Basic Education introduced English across the curriculum strategy (EAC) to bridge the barrier of the language of teaching and learning that is implemented in all content subjects, including Technology. This strategy of implementing content subjects involves the integration of English language skills into technology when the teachers are teaching.

These skills include speaking and listening, writing and presentation, reading and viewing and language (application of language structures) (Education, 2013). An example of the implementation of EAC could include reading the extract or scenario or case study with electric circuits, simulation, or video-related electric circuits, viewing the electric circuits extracts, videos and simulations and answering the questions. The questions may require the learners to summarise what they have viewed or read, or they can do presentations regarding what they have viewed or done. It is therefore important for the teacher to have knowledge of diversity and inclusivity to address the barriers of the learners.

2.6.1.9 Category: Various contexts in which teaching of electric circuits takes place

The teachers should also know context in which learning and teaching take place. Bennett et al. (2008) refer to knowledge of context as all contextual factors that impact teaching, for example, the resources, class size, students' socio-economic background, curriculum, the situation in the country, classroom conditions and time available for teaching and learning.

This necessitates the teacher to possess knowledge of the context when teaching electric circuits since the performance of the learners is impacted positively or negatively by the context. Technology teachers teach the learners to apply authentic contexts based on real-life situations outside the classroom and it develops vital problem-solving skills that will benefit every learner in life contexts (Education, 2011b).

2.6.1.10 Category: Teaching resources for electric circuits

The teachers' knowledge of the resources is vital when teaching electric circuits since they allow the teacher to teach effectively. Kind (2007) mentions the resources that enrich teacher efficacy, including equipment, books and other materials that increase the learning prospects in the classroom. Therefore, the teachers should know the resources, and this could be ascertained through TSPCK.

2.7 Content representations

Another model that is used to capture the teachers' TSPCK in this study is CoRes. CoRes are suitable for getting an insight into how teachers transform content knowledge into teachable form that could be understood by the learners. The following scholars highlight the suitability of CoRes when studying TSPCK. Mavhunga and Rollnick (2017) state that it is suitable to use CoRes to make the invisible PCK knowledge visible, to analyse teaching and to depict how teachers reason about the topic. Lockley and Williams (2012) developed the Science CoRes that could be used by other subjects. CoRes is used in this study to capture the teachers' TSPCK and is adapted from the study that was conducted by (Zimmerman, 2015). The CoRes organises knowledge and PCK within a specific topic (Zimmerman (2015). The questions of the TSPCK assessment tool and CK assessment tools that were developed by (Zimmerman, 2015) are aligned with CoRes. This questions in this study were aligned with the CoRes adapted from (Zimmerman, 2015).

The themes in this study were predetermined as TSPCK categories and assisted to explore the teachers' TSPCK. The questions were aligned to these categories that formed themes, including learners' prior knowledge and misconceptions, curriculum saliency, difficult ideas to teach in electric circuits, representations, conceptual teaching strategies of electric circuits of electric circuit, learners' diversity for inclusive teaching of electric circuits, technologies for teaching electric circuits, various contexts in which teaching electric circuits takes place, assessing electric circuits and teaching resources for electric circuits. These themes emanate from studies by (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015).

2.8 Pragmatic framework

Pragmatic philosophy's view considers that the actions of human beings cannot be treated in isolation considering their past experiences and the beliefs emanating from those experiences; human thoughts are inherent, and there is a connection between thoughts and human actions. The connotation of the actions of human beings originates from their consequences; the human beings' experiences are formed by means of their actions and intelligence, and the external forces do not shape human beings; the reality is not fixed, and it transforms; the world is not fixed, and it is in a continuously changing. The world transforms through actions; actions transform reality; the way the world is viewed is affected by social experiences; knowledge is constructed through individual experiences; knowledge is shared socially as it develops from socially shared experiences (Kaushik & Walsh, 2019).

Wahyuni (2012) echoes that in pragmatic paradigm the reality is constructed externally, there are many realities, the view is selected to best attain an answer with regards to the research question, meaning is subjective and it is provided by either or both observable phenomenon relying on the research question, it pays attention to applied research, combining various perspectives to assist interpret data., it considers values in interpreting results, the researcher, can be both objective and subjective, it supports quantitative and qualitative or mixed method design.

The pragmatic framework relates to this study since it is not fixed. That means that the researcher is free to choose what is regarded as suitable to answer the research question. Data collected emanated from the experiences of the participants. The views of the respondents were considered, and the meaning was subjective, different perspectives were accommodated. Since the mixed methods approach was being used, the CK assessment tool and TSPCK tools that were used to collect data were chosen because they are regarded as suitable tools to collect data amid Covid-19.

2.9 Teacher development programmes

It was envisaged that this study would also lead to the identification of relevant teacher support programmes by getting insight into the teachers' TSPCK when teaching electric circuits. The teaching of electric circuits might be enhanced. According to (Mavhunga & Rollnick, 2013), professional programmes should develop PCK at topic level (TSPCK) since it involves a conceptual understanding of its components and their interaction.

Different studies suggest that teacher development programmes regarding TSPCK components should be conducted. These studies include the study conducted by (Mafa-Theledi et al., 2020) recommending that Economics teachers must be offered opportunities to assist them develop TSPCK of content as part of their professional development.

Hallstro¨m et al. (2017) claim that teachers should be provided with ongoing support and in-service training since sometimes the teachers are well acquainted with some topics yet not confident to teach other topics like confident in teaching electronics yet not self-assured in teaching electricity and Technology systems. They become beginners when teaching new topics and topic-specific representations (Rollnick, 2016). They concluded that the teaching practices of experienced teachers present useful information about the future development of teachers, teacher education and professional development courses (Fahrman et al., 2019).

2.10 Conclusion

In conclusion, the deliberation makes it clear that to understand the level of the teachers' TSPCK and CK and the relationship between the two, one needs to understand the literature regarding technology as a subject, teaching, PCK, TSPCK, frameworks from which the conceptual framework of this study emanate, content representations, pragmatic framework, and teacher development programmes.

Technology is a new subject without fully established literature; for the teachers to teach, they should know what to teach and how to teach for them to change the content they are teaching to what could be understood by the learners. This means teachers should have a well-developed TSPCK and CK, hence it is imperative to study the teachers' TSPCK when teaching electric circuits. The CoRe and pragmatic frameworks served as the philosophy for this study. The study could suggest developmental programmes based on the findings.

CHAPTER THREE

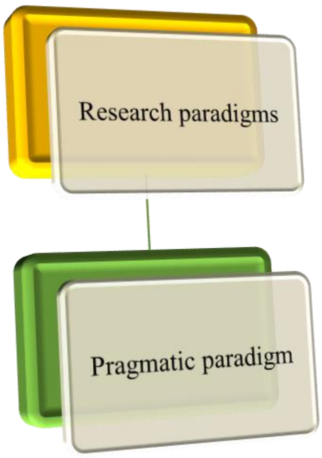
3. Introduction

In this chapter, the following aspects are discussed: Introduction, research paradigm, research design including research methodology, strategy of inquiry, sampling and sampling methods, data collection as well as reliability, validity, credibility, confirmability, transferability, dependability, flexibility, and ethical considerations.

3.1 Research paradigms

The research paradigm that was employed is the pragmatic paradigm.

Figure 3.1Illustration of research paradigm



The pragmatic paradigm was appropriate for this study because it related to a mixed methods approach as stipulated by (Clark & Creswell, 2011). The convergent method that is centred around the pragmatic paradigm was employed. According to (Clark & Creswell, 2011), the convergent design interaction level is dependent on the pragmatic paradigm; there is equal focus with regards to qualitative and quantitative research methods. Besides, qualitative, and quantitative designs occur simultaneously; there is independent interpretation; there is interactive analysis and analysis of qualitative and quantitative is done separately. Thereafter, results are combined; there are parallel databases.

This means this paradigm involves concurrent qualitative and quantitative research. In this study, both qualitative and quantitative designs took place simultaneously, the interpretation was done independently, and the results were combined to ascertain the correlation between TSPCK and CK. In this paradigm, the researcher does not have boundaries in terms of the data collection methods. The researcher decides in terms of what is suitable to answer the research question. In this study, for instance, the CK assessment tool and TSPCK assessment tools were used to collect data.

The research methodology that was employed is mixed methods approach which relates to pragmatic paradigm. The teacher's views were taken as they were to inform the findings of this study. Multiple views of the participants were taken into consideration. The meaning of the findings was interpreted using predetermined categories that formed themes.

3.2 Research methodology

This study employed the mixed research method. According to (Cresswell & Cresswell, 2018), it includes the collection of qualitative and quantitative data to answer the research questions; it comprises rigorous methods, including data collection, data analysis and interpretation of qualitative and quantitative data; these qualitative and quantitative types of data are incorporated into the design analysis by combining the data, explaining the data. This methodology is based on philosophy or worldviews, as well as theory. Hence, mixed methods can refer to the use of both quantitative and qualitative methods to answer research questions in a single study, as well as those studies that are part of a larger research programme and are designed as complementary to provide information related to several research questions, each answered with a different methodological approach.

Mertens (2015) states that the mixed methods approach means the utilisation of qualitative and quantitative methods, and these methods supplement each other by offering data to respond to the research questions; each method utilises a different methodological approach. Mertens (2015) also provides the significance of the mixed methods approach, including that it incorporates both qualitative, quantitative, and mixed methods; responds to the research questions that could not be responded to in one way or another and it enhances the researchers' potential to infer conclusion regarding the problem.

This means when the mixed methods approach is utilised to gather data, it is premised on data gathering involving qualitative and quantitative methods; it involves data collection data analysis and interpretation of data; it is also informed by the philosophy or worldviews and theory. The research questions are responded to by employing qualitative and quantitative designs in one study.

It shows that the mixed research method provides the answer to the research question that could not be addressed in one way or another. Researchers apply the mixed methods approach in research because it leads to the conclusion and answers the research question.

Cresswell and Cresswell (2018) provide the reasons for choosing the mixed method for instance it caters for both qualitative and quantitative methods, it decreases the shortfalls of each other which means these methods complement each other; it provides that bigger picture of the study regarding the actual understanding of the data that is collected, which assists to answer the research question; it serves as an approach that is relevant to new research procedures. In other words, it even fills the gaps that exist if one methodology is utilised; it completes the process of data collection, data analysis and interpretation of qualitative and quantitative data by providing a complete picture when answering the research question emanating from both qualitative and quantitative viewpoints.

Mertens (2015) also asserts that mixed methods could be utilised to compare the qualitative results and quantitative results of the study through triangulation; it allows complementarity whereby the findings from the quantitative method inform the findings of the qualitative method and it seeks illustration, improvement, and explanation of the findings regarding qualitative to quantitative method. Also, it develops the breadth of the study; it uncovers paradoxes and contradictions because of comparing the two analytical strands.

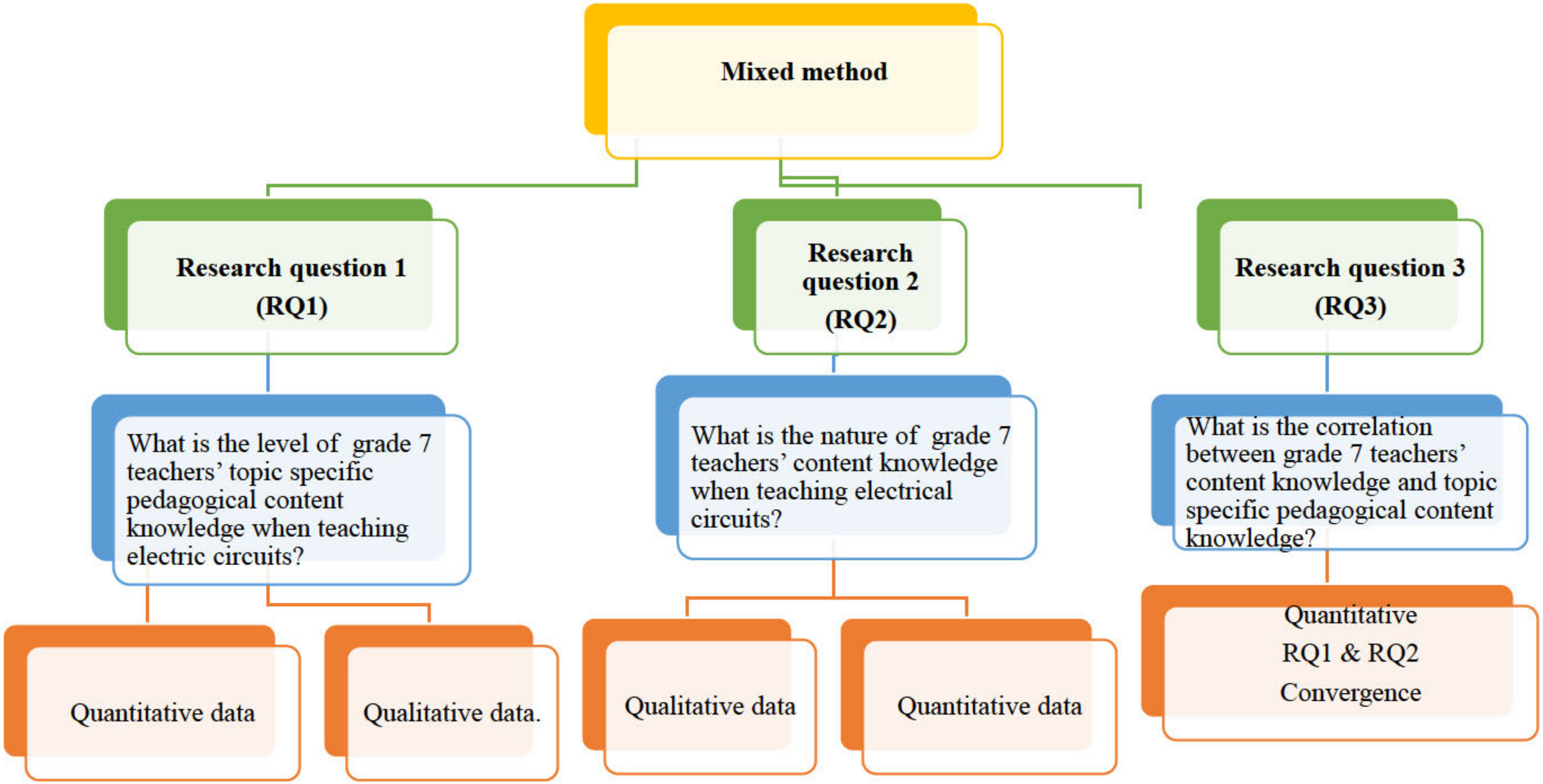
In this study, the mixed methods approach was chosen because it generates a complete picture with regards to data that was collected. The TSPCK assessment tool and the CK assessment tools were analysed and interpreted both qualitatively and quantitatively. These methods supplemented each other thus decreasing the shortcoming of each other.

In this study, the mixed methods design involved convergent mixed methods design. With regards to (Cresswell & Cresswell, 2018), the convergent mixed method involves the collection of quantitative and qualitative data; data are analysed independently and then the results are matched to ascertain if the results confirm or disconfirm anything.

Data were collected qualitatively using the TSPCK assessment tool and quantitatively using the CK assessment tool. Data were analysed separately and after that, the results were matched to establish the relationship between the CK and the TSPCK of the teachers when teaching electric circuits.

The mixed method approach linked to the research questions was used to collect data and analyse it as illustrated in Figure 3.2.

Figure 3.2: Mixed methods approach and corresponding research questions



3.3 Strategy of enquiry

The study employed the mixed methods approach. The strategy of enquiry that was used to explore the teachers' TSPCK considering electric circuits was a case study. It was linked to the qualitative part of the mixed methods approach.

The multiple case studies comprising a sample of four teachers from four schools were used to collect data regarding grade 7 teachers' TSPCK when teaching electric circuits. The scholars provide the meaning of the case study. The case study is the strategy of a research study involving exploring in-depth the process, a phenomenon, one or more individuals or multiple cases (Cresswell & Cresswell, 2018). Yazan (2015) affirms that the case study is an enquiry that involves a certain individual, occurrence or case in order to understand that phenomenon. Mertens (2015) adds that the case study focuses on the interaction of the phenomenon. Smith and Wood (2016) also asserts that that the case study captures the participants' in-depth views. Henning et al. (2009) share the sentiment that it is used to study the in-depth understanding of the situation and meaning of those involved, and (Cohen et al., 2007) add that it also captures their experiences. The case study leads to qualitative research (McMillan & Schumacher, 2006). They further provide the purpose of the case study, including that it gives the details of the concept and develops a model with its related subcomponents or suggestions.

This indicates that the case study provides the details with regards to the phenomenon that is being studied which could be an individual or multiple case studies; it also includes individuals or happenings. The case studies are suitable for this study since this study used qualitative method as part of mixed method. Mertens (2015) also indicates that the qualitative study involved case study.

A case study is suitable for getting insight, improving, reforming practice and reflecting (Cohen et al., 2007). Since the case study assists in ascertaining the insight into the phenomenon being studied, it led to looking back to determine the successes and failures to enhance and change the performance. It provides understanding and meaning of individual and social actions in a certain context (McMillan & Schumacher, 2006).

A case study in this study assisted the researcher to understand the teachers' TSPCK when teaching electric circuits. This study employed multiple case studies. The findings of each participant were combined to come up with a conclusion. It was used to get an in-depth understanding of the teachers' TSPCK when teaching electric circuits. A study is also suitable for the qualitative part of mixed methods research; therefore, it was relevant for this study.

Sampling was done to come up with the four case studies from four schools. This was done based on the notion that it is appropriate for studying small samples in real-life occurrences, as well as real-life context as highlighted by (H.Taherdoost, 2016; Yin, 2003).

3.4 Sampling and sampling methods

A mixed methods approach was used to explore the teachers' TSPCK. The sampling in this study related more to qualitative part of the mixed methods approach. The sampling methods involved target population, sampling frame, technique, size of the sample and data collection (H.Taherdoost, 2016). Numerous case studies were employed involving four grade 7 teachers from four schools in Lower Umvoti Circuit to get a clear understanding of the teachers' TSPCK when teaching electric circuits. The sample of 4 teachers was relevant to the study since qualitative research supports small groups as stated by (McMillan & Schumacher, 2006).

The sampling method used to select the participation in this study is non-probability purposeful method. The non-probability sampling is one of the cheapest methods of sampling that accommodates certain groups of participants, and the participants are chosen deliberately as reiterated by (Cohen et al., 2007). Purposeful sampling was used to collect data since it is used in qualitative research as stated by (Duan et al., 2013). Charles et al.(2015) refers to purposeful sampling as choosing the participants that are rich in terms of the appropriate data that are to be collected.

Purposeful sampling was used in this study to capture data since it involves the selection of the experienced individuals or group with regards to the phenomenon to be studied as stipulated by (Duan et al. (2013)). Leedy and Ormrod (2015) reiterate that purposive sampling involves selecting participants that can offer the required angle with regards to the topic or what is being studied. The sample selection relates to the pragmatic paradigm because it considered the teachers' views.

The procedures and the processes considered to recruit the participants should be clearly stipulated as articulated by (Cresswell & Cresswell, 2018). They also state that the selection approach, inclusion and exclusion criteria, the number of participants and compensation should be indicated. The participants were recruited using the questionnaire that was sent to the participants using an Microsoft form link, and the participants submitted using WhatsApp. The participants were grade 7 Technology teachers that had experience in teaching electric circuits in Lower Umvoti District in Kwazulu-Natal province.

The experienced Technology teachers were selected to participate in this study because they were rich informants of the data required since they had taught the electric circuits. The experienced teachers' reflections and practices provided in-depth understanding of the teachers' TSPCK when teaching electric circuits. The schools were selected from this Circuit because the Circuit was prioritised for curriculum support. The participants did not benefit financially from the study.

3.5 Data collection

Data were collected from four Technology grade 7 teachers to explore their TSPCK when teaching electric circuits. The questionnaire was sent to the teachers recruiting them to participate in a study. The notional time disruption was avoided when data were collected.

A mixed methods approach was used to collect data because it answered the research question, as the study related to a pragmatic research paradigm. The pragmatists regard the research question as more significant as compared to the method that is utilised or the worldview that is related to the method; the researchers utilise the "criterion what works" (Mertens, 2015, pp. 371) with regards to the method that is utilised. This means in a pragmatic approach; the researcher chooses the method that succeeds in answering the research question.

Data were collected by using the CK assessment tool and TSPCK assessment tool in a form of a questionnaire. Data were collected in parallel whereby the qualitative data collection using the TSPCK assessment tool questionnaire took place prior to quantitative data collection using the CK assessment tool questionnaire. Mertens (2015) articulates that in mixed methods, qualitative and quantitative data collection take place alongside each other. A questionnaire is a tool employed to gather data according to (Fox et al., 2007). According to (Cohen 2013), a questionnaire is used to gather primary data. The CK assessment tool was adapted from a (Zimmerman, 2015) study. The TSPCK assessment tool was adapted from(Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015).

The links for TSPCK and CK assessment tools were developed using Google Docs but only one teacher was able to respond to it because the other teachers were unable to download it. The questionnaire was sent to the participants and submitted online as stated by (Taherdoost, 2016). The CK and TSPCK assessment tools were sent to the participants and submitted using WhatsApp. The communication was done using cell phones due to Covid-19 restrictions. The whole process took two months since there were examinations in between. The first TSPCK questionnaire was sent to participants in advance, thereafter the second CK assessment tool was sent. The second tool was sent four days after the first one.

The CK questionnaire has items for questions and instructions. Cresswell and Cresswell (2018) state that a sample item involves items from the data collection instrument to allow the readers to view the items that are included in the instrument. A questionnaire is a tool employed to gather data according to (Fox et al., 2007). This is also articulated by (Cohen 2013) when stating that the questionnaire is used to gather primary data. According to (Engelhardt, 1997), when the questionnaire is administered, there is no need for the researcher to be present, except if there are questions that need clarity; it could be utilised for sampling the content.

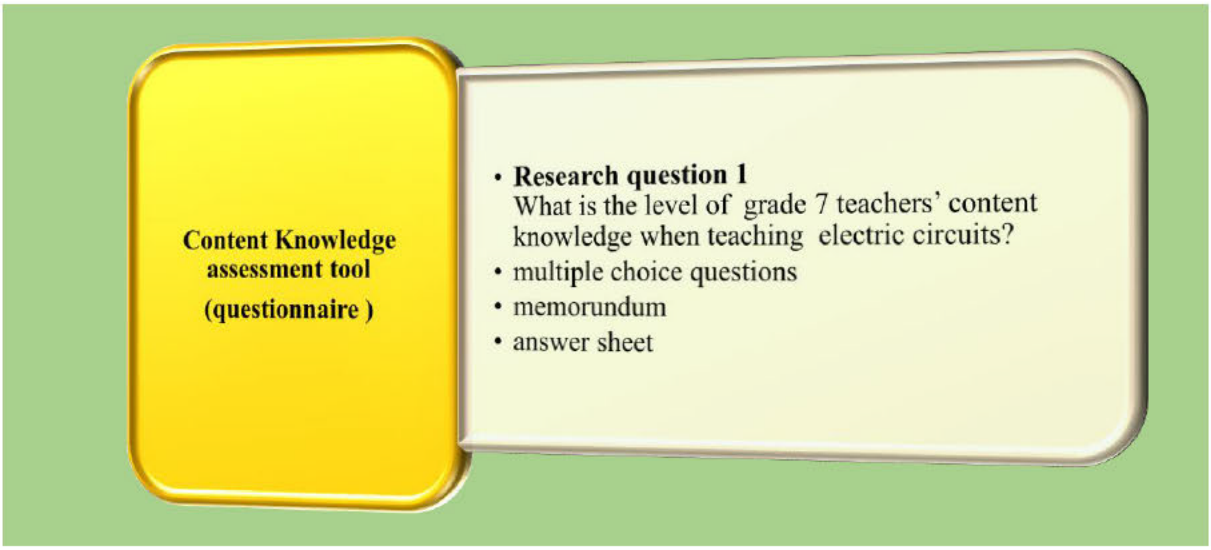
A questionnaire is a research tool that consists of questions that are used to gather data; it is utilised to gather information/data regarding personal views and opinions or sentiments. The different scholars point out the advantages and disadvantages of the questionnaire. The advantages of the questionnaire are that it is used to gather lots of data from people in a non-intimidating manner; the questionnaire could be done without disclosing your identity; it is uncomplicated to compare and analyse; it could be conducted with numerous people and can be used to gather a lot of data; numerous samples of a questionnaire are already available (Mertens, 2015). In addition (Dolowits et al., 2008) highlight the advantages of the questionnaire include acquiring variety and deepness of data; its administration and presentation of questions is not rigid. The disadvantages of the questionnaire include that it is time consuming; data can be hard to analyse and compare (Dolowits et al., 2008).

As much as a questionnaire has disadvantages, in this study it was useful because the researcher did not conduct research physically due to Covid-19 restrictions, and it captured the illustrations perfectly as compared to other methods. Dolowits et al. (2008) highlight that in the questionnaire, the questions should not be ambiguous, thus questions should be understandable; the questions could be semi structured using closed ended questions or closed ended questions. They further articulate open ended questions are valuable since they involve the participants' expression, in closed ended questions, the required response is determined; data are ranked; results are represented in terms of the statistics. In this study the questions were both open ended, closed ended and clear. The participants expressed their views and experiences as they answered the questions. The results were represented qualitatively and statistically.

3.5.1 CK assessment tool

The CK assessment tool questionnaire was used to collect quantitative data, and qualitative data related to the teachers' teaching of electric circuits. The questions in the CK assessment tool answered research question 1 as illustrated in Figure 3.5.1.

Figure 3.5.1 CK assessment tools



Quantitative data and qualitative data were collected using the questionnaire of the CK assessment tool adapted from the CK assessment tool developed by (Zimmerman, 2015). The CK assessment tool consisted of twelve multiple choice questions that were done for an hour.

The questions in this CK assessment tool questionnaire examined what was known by the respondents about electric circuits. This was aligned with what is indicated by (Mertens, 2015) that the questions in the questionnaires are similar to those in school tests, and they test how much a person understands a certain subject. The CK tool with multiple choice questions was selected for this study because in multiple choice questions there are minimal mistakes since they are subjective. Besides, statistical methods can be employed to this data, and it is not time consuming when administered.

The CK assessment tool assessed the content knowledge of the participants and mapped out the misconceptions of the participants. Therefore, in this study, the questionnaire was used for content sampling as indicated that the questionnaire could be used for content sampling.

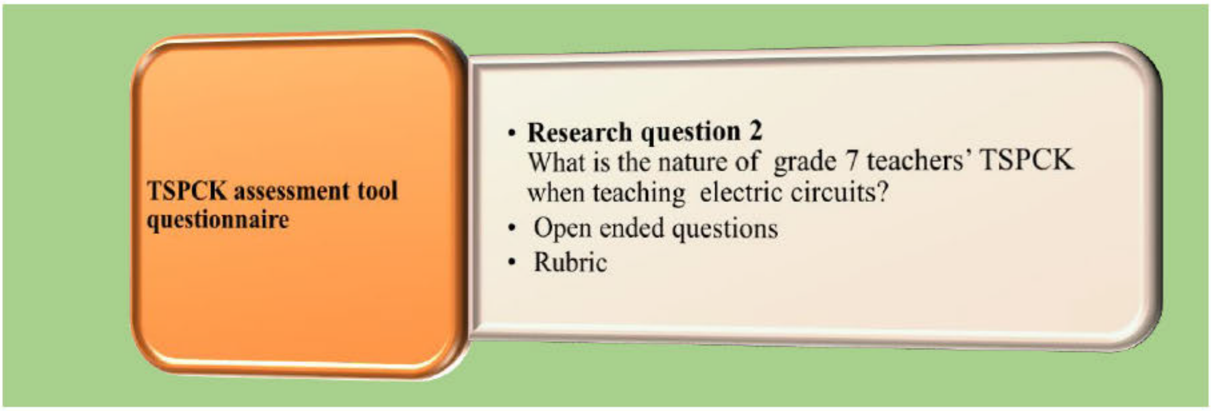
Multiple choice questions were used to collect data using CK assessment tools. In the multiple-choice questions, the response alternatives were provided, and participants chose the correct response. The participants responded to questions on their own. Besides, the techniques that were used to administer the questionnaire included sending the questions to the participants via WhatsApp. The questions for the CK assessment tool questionnaire are listed in Annexure 4. The memorandum that was used to rate the participants' responses quantitatively and qualitatively is attached as Annexure 5.

Qualitative data in CK assessment tool involved classification of teachers' knowledge in terms of levels for instance limited, basic, developing, exemplary. The qualitative confidence levels were used to limit guessing when answering multiple choice questions. The participants had to indicate response and confidence levels, including blind guessing, completely sure, confident and a bit unsure. The answers that were regarded as correct had the confidence level of completely sure and confident. CK answer sheet attached as annexure 10.

3.5.2 TSPCK assessment tool

A qualitative questionnaire for the TSPCK assessment tool was used to collect data regarding the teachers' TSPCK when teaching electric circuits. The questions in the TSPCK assessment tool answered research question 2 as illustrated in Figure 3.5.2.1

Figure 3.5.2.1 TSPCK assessment tool questionnaire



The qualitative data were collected using the questionnaire of the TSPCK assessment tool adapted from the TSPCK frameworks developed by (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015). The TSPCK assessment tool was selected because it was suitable for collecting qualitative data involving teachers' TSPCK when teaching electric circuits The participants were free to raise their views as stipulated by (Rani & Roopa, 2012). The TSPCK content includes the content that is covered in CAPS Technology grades 7-9 (Education, 2011b) which relates to electric circuits comprising simple electric circuits with an energy source (cell) switch conductor and a light bulb.

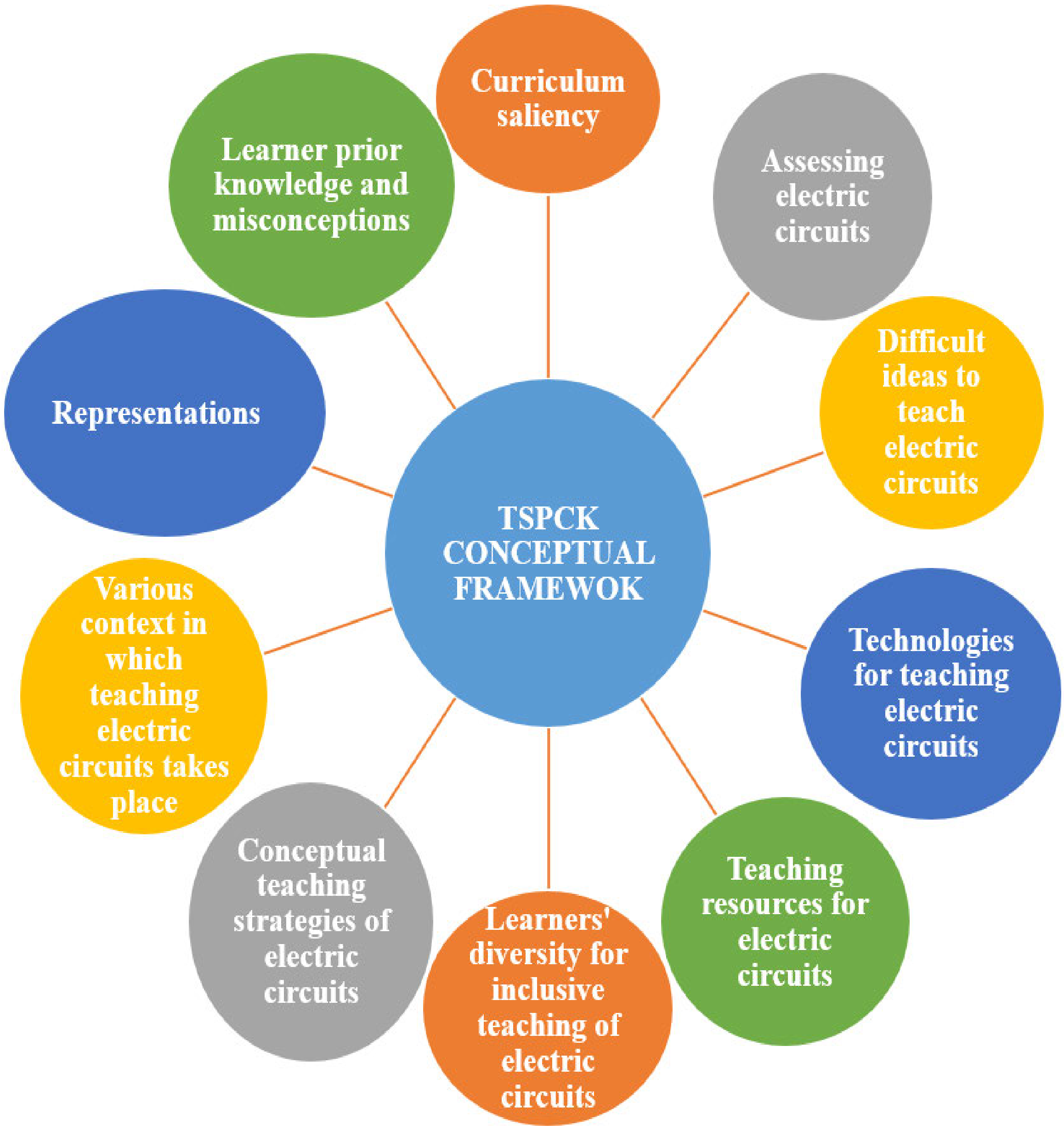
In terms of CAPS, the depth of simple circuits is not indicated. It is not indicated whether the simple series or parallel circuits or both should be done. Nothing is directly said about complete circuits, current, voltage, an electric field and resistance. But when you look at this content, the teacher should be able to know this content since it is indirectly applied when teaching the circuits, and if the teachers do not understand this content, the teacher will not be able to identify problems if the learners are assembling the circuits or drawing electric circuits. This also highlights the significance of the teacher's knowledge of transforming content into teachable form.

Considering these deliberations, the content area for this study was adapted from TSPCK assessment tool that was developed by (Zimmerman, 2015). This included the content of complete circuits, current, voltage, electric field, resistance, series, and parallel components. TSPCK comprised TSPCK knowledge categories as adapted from (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015). It includes learner prior knowledge and misconceptions; various contexts in which teaching electric circuits takes place; difficult ideas to teach electric circuits; technologies for teaching electric circuits; representations, teaching resources for electric circuits; learner diversity for inclusive teaching of electric circuits; conceptual teaching strategies of electric circuits; assessing electric circuits and curriculum saliency.

The questions in this TSPCK assessment tool questionnaire explored the TSPCK of teachers when teaching electric circuits. The questions were adapted from (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015) studies involving TSPCK, and some questions were developed by the researcher since the research is limited in Technology. It is difficult to get relevant Technology framework for this study. The questions were linked to TSPCK components. The questions linking to a study by (Azam et al., 2019) involved TSPCK components including teaching resources, technologies used for teaching technology, student diversity for inclusive technology education and various contexts in which teaching takes place. Some questions were linked to studies by (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015).These questions included TSPCK categories including what is difficult to teach, representations, conceptual teaching strategies, curriculum saliency. Questions linked to learner's prior knowledge and misconceptions questions category for this study were adapted from (Zimmerman, 2015).

The questions considered the conceptual framework for this study including categories curriculum saliency; various contexts in which teaching electric circuits take place; difficult ideas to teach in electric circuits; technologies for teaching electric circuits; teaching resources for electric circuits; learners' diversity for inclusive teaching of electric circuits; conceptual teaching strategies of electric circuits; representations; assessing electric circuits; learner prior knowledge and misconceptions. The conceptual framework that was employed in this study is depicted in Figure 3.5.2.2.

Figure 3.5.2.2 TSPCK Components of Conceptual Framework



The TSPCK assessment tool questionnaire consisted of qualitative open-ended questions and a few closed ended questions that were used to collect qualitative data for this study. It was developed to unearth the teachers thinking and knowledge of changing what is taught to teachable form when teaching electric circuits. The participants responded to questions and their views, experiences and reflections were considered. It took 1 hour 30 minutes to complete the questions.

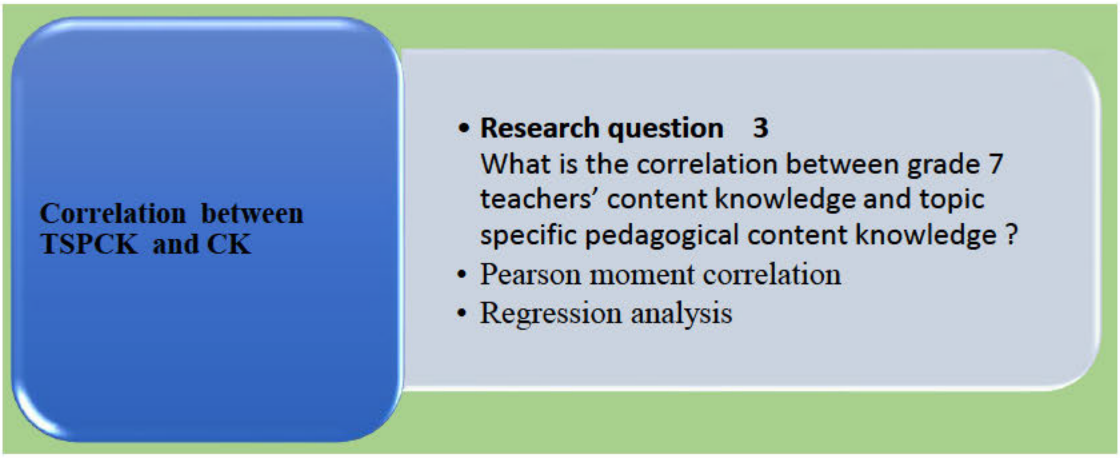
The TSPCK assessment tool questions were sequenced according to different knowledge categories adapted from (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015) studies as depicted in Figure 3.5.2.2 The TSPCK assessment tool questionnaire questions were answered by the participants. The rubric that was used to rate the participants' responses qualitatively was attached as Annexure 7.

According to (Abdulla&Halim, 2010), some phases of developing the instrument involve selecting the domains indicators by creating an instrument. TSPCK instrument was developed. The TSPCK components adapted from (Azam et al., 2019; Mavhunga & Rollnick, 2013; Zimmerman, 2015) studies were identified to form a conceptual framework for this study. The content that was to be included was identified, TSPCK conceptual framework was developed, rubric was developed and aligned to TSPCK assessment tool categories in Figure 5.2.2.2. The rubric's qualitative ratings included limited, basic, exemplary, and developing. The rubric had descriptors linked to these ratings. The ratings were converted to quantitative data for example limited -1, basic - 2, developing -3 and exemplary - 4.

3.5.3 The relationship between CK and TSPCK data

This section deals with the data about the relationship between CK and TSPCK. These data answered research question 3 depicted in Figure 3.5.3. Data were obtained by establishing the relationship between TSPCK and CK using the Pearson moment correlation scale and regression analysis.

Figure 3.5.3 Correlation between TSPCK and CK



3.6 Credibility, confirmability, dependability, transferability, flexibility, validity, reliability, ethical consideration.

Credibility, confirmability, dependability, transferability, flexibility, validity, reliability, and ethical consideration were accomplished in this study.

3.6.1 Validity

Validity was achieved through quantitative validity and content validity. Some questions in the assessment tools were adapted from (Zimmerman, 2015) hence validity and reliability was ensured. In a study that was conducted by (Zimmerman, 2015) it was revealed that there is reasonable possibility that the results of the TSPCK assessment tool that was developed can yield the same results. In a study that was conducted by (Zimmerman, 2015) The CK and TSPCK assessment tools were valid since they had approppriate statistical range to ensure validity.

3.6.1.1 Quantitative validity

Quantitative validity entails the scores obtained by the participants that are the profound pointers of the idea that is being assessed, and the measures are sourced from external sources to the participants and researcher, that is, statistical procedures or external experts (Clark &

Creswell, 2011). The utilisation of the available instrument depicts the verified validity of scores attained from past utilisation of the instrument (Mertens, 2015).

This indicates that quantitative validity is represented by the scores that are obtained by the participant that show what is measured. In this study, qualitative validity was achieved since the CK assessment tool was adapted from an existing one developed by (Zimmerman, 2015) and was subjected to quantitative and qualitative analysis to ensure validity. Validity was done interpretatively and statistically. What was measured was depicted in the CK assessment tool in which the participants were rated statistically using levels 1, 2, 3 and 4 and interpretatively using the confidence levels, including blind guessing, completely sure, confident and a bit unsure to eliminate guessing. In the TSPCK assessment tool questionnaire, the participants responses were rated using ratings, including limited, basic, developmental, and exemplary.

Quantitative validity was achieved by using the Pearson product-moment correlation and regression analysis to establish the relationship between quantitative and qualitative data, for instance, CK and TSPCK of teachers when they teach electric circuits.

3.6.1.2 Content validity

Content validity is the extent to which the test entails the relevant content that it is supposed to assess; the researcher should ensure that the test covers the relevant content (Mertens, 2015). This highlights that the test should assess what it anticipates assessing. In the CK assessment tool questionnaire, the questions were checked to establish that they were the ones that needed to be assessed, and they are aligned to CAPS, while some aligned to what the teacher should know when teaching electric circuits.

3.6.2 Quantitative Reliability

Quantitative reliability refers to the scores that are obtained from the participants that are consistent and stable over time; the reliability of scores should be ascertained before assessments of their validity can be attended to (Clark & Creswell, 2011). The scores' reliability on the instrument means that if the instrument is implemented in a similar situation, it can yield the same results. Internal consistency of the instrument is the significant type of reliability for multi-item instruments; internal consistency is the extent to which the collection of items is conducted/behaves similarly (Mertens, 2015). Quantitative reliability of the assessment tool questionnaire was achieved because the results of this study, in some questions, were congruent with other studies.

Some questions in the assessment tools were adapted from (Zimmerman, 2015). It was revealed that there is reasonable possibility that the results of the TSPCK and CK assessment tool that were developed can yield the same results. The CK and TSPCK tools were piloted before administration in this study. The adapted TSPCK rubric was used to rate the responses. The assessment rubric is a significant component of ascertaining the validity and reliability of the TSPCK assessment.

The rubric that was developed by (Zimmerman, 2015) achieved a good level of agreement and indicated an acceptable level of reliability with regards to the scoring of responses. Reliability was achieved when CK assessment questionnaire was piloted before it was administered in this study. The questions in the CK tool are consistent, precise, and unambiguous. In some questions, participants obtained the same results as they had undergone the same questions in a study from which they were adapted. However, the contention would be whether the other participants teaching electric circuits could achieve the same results.

The part of the study that involves qualitative data using the TSPCK assessment tool employed the criteria suitable for ensuring trustworthiness in interpretative research as recommended by (Guba, 1981). He points out that these criteria include credibility, confirmability, transferability, and dependability. The quantitative processes were not used in isolation but in conjunction with qualitative methodologies. The qualitative data collection involving the TSPCK assessment tool employed the criteria involving confirmability, transferability, credibility, and dependability.

3.6.3 Credibility

Credibility means a degree to which the findings of a study represent what happened as stated by (Bonney et al., 2017). Credibility was maintained by ensuring the accuracy of the questionnaires. The findings were made available to the participants via WhatsApp, and the participants went through the data of the study to confirm the inclusion of what happened in this study. The sample consisted of four experienced teachers since they were teaching electric circuits thus a source of rich data. The TSPCK assessment tool questionnaire comprised questions that were aligned to TSPCK components, and the questions were pre-categorised according to different knowledge domains which made it easier to analyse and interpret the data that were collected. The questions were concise, precise, and free from errors. Some questions were adapted from the (Zimmerman, 2015) study therefore credibility was maintained.

3.6.4 Confirmability

Confirmability means the extent to which the findings of a study could be confirmed in other studies as posited by (Korstjens & Moser, 2017). In this study, it was accomplished through triangulation. According to (Cohen et al., 2007), methodological triangulation involves utilising either the same research method on different cases or the different methods on the same study. The administration of the questionnaire by the participants, involving multiple case studies of four Technology teachers was used to collect data using the TSPCK assessment tool to ensure confirmability. This ensured that data collected, and the findings were not influenced by the researcher's views. Some findings in this study were confirmed by other studies.

3.6.5 Transferability

Transferability means the extent to which the results could be used in other contexts, and by other participants, and it could be achieved through description as stated by (Guba & Lincoln, 1986). The contextual factors and the participants of the study were clearly described as in the context of the research was indicated; the teachers were at schools where learning and teaching took place; the researcher did not come to the school due to Covid-19 restrictions, but the TSPCK assessment tool questionnaire was administered, sent, and submitted by WhatsApp and google docs. This tool was used to establish the nature of TSPCK when the teachers teach electric circuits. The participants had the experience of teaching electric circuits hence data informant. The participants were recruited using Microsoft form questionnaire. Data collection involved experienced teachers to maximise trustworthiness. The findings' report was compiled and made available. It was left to the discretion of the reader whether the findings could be used in other contexts or not.

3.6.6 Dependability

Guba (1981) states that dependability involves an overlap of methods used to collect data. In this study, it is not only the TSPCK assessment tool questionnaire that was administered for the CK assessment tool questionnaire too was also administered. In this study, the TSPCK assessment tool questionnaire had questions that were consistent, hence it could produce the same results even if administered later. This questionnaire maximised the effectiveness of the process of collecting data.

3.6.7 Flexibility

Flexibility means the relationship that the researcher is having with the participants and self-reflection about oneself, the researcher regarding preconceptions, biases and preferences as reiterated by (Korstjens & Moser, 2017). Flexibility was ensured by interpreting the results of the qualitative TSPCK assessment tool questionnaire accurately to reduce bias. The participants were not exposed to harm and were protected because the questionnaires were sent using WhatsApp, and online Google Docs were used due to Covid-19 restrictions.

The participants might benefit from the study. The participants were treated with respect and to protect their dignity. The identities of the participants were protected, and anonymity was maintained by using pseudonyms instead of their actual names. The participants were assured of confidentiality by the researcher through the letter requesting permission to conduct a study from the school (Annexure 2) and the participant' consent (Annexure 3). Transparency was exercised, and the participants were assured that they had authority over their reflections and what they shared.

3.6.8 Ethical consideration

The topic, purpose, objectives, and the intended use of the study were communicated to the principals, teachers, KwaZulu-Natal Department of Education, and the University of KwaZulu-

Natal. Their participation in this study did not disturb tuition time or any work-related responsibilities.

The documents were sent via WhatsApp and online using Google Docs and Microsoft form. The participants were assured that the participation was voluntary, and they could withdraw from the study at any stage. The choice not to participate in this study did not jeopardise the study although four targeted participants declined. Only pseudonyms as participant numbers were used (P01, P02, P03 and P04). There were no financial benefits involved in this study since the research was done for academic purposes.

The findings of the research study were made available to the participants. Data collection documents were treated with confidentiality and submitted to the supervisor. The documents would be kept by the university for 5 years, and after that, they will be deleted from electronic devices.

The ethical considerations when conducting the study comprise the purpose of the study, consent, ensuring anonymity and confidentiality as pointed out by (Sharp, 2012). McMillan and Schumacher (2006) emphasise that the researcher should gain permission to use the site and ensure confidentiality, privacy, and anonymity. Henning et al. (2009) emphasise that informed consent should be given to the participants' organisations and explain the proposed use of data and the reason for sampling. The use of the site should be explained as well (McMillan & Schumacher, 2006).

The ethical clearance to collect data from the schools and the teachers was obtained from the university and the gatekeeper's authority of the KwaZulu Natal Department of Education authorised data collection. The researcher gained permission to conduct research from the school principals. The teachers provided consent to participate in this study. Leedy and Ormrod (2015) stipulate that the consent forms should be signed by teachers. The consent form and the request for permission to conduct research were sent to schools and teachers via WhatsApp.

The steps of the research were communicated to the participants as stated by (Sharp, 2012; Smith & Wood, 2016), as well as the activities involved as denoted by (Leedy & Ormrod, 2015). These steps and activities involved were communicated to the participants via the telephone.

To introduce and motivate participation, the researcher contacted the schools and the teachers telephonically. The reason for the research was explained and the length of the questionnaire and its intended use were indicated as pointed out in (Bird, 2009). The low response rate was addressed by sending the questionnaire again as stated by (Bird, 2009).

3.7. Conclusion

The study focused on the pragmatic research paradigm, and the research methodology that employed was a mixed method one. The strategy of enquiry employed was the case study, and purposeful sampling was used to select the participants. Data were collected using CK and TSPCK assessment tools. Besides, credibility, confirmability, dependability, transferability, flexibility, validity, reliability, and ethical considerations were maintained.

CHAPTER FOUR: DATA ANALYSIS, FINDINGS, AND INTERPRETATION

4.1 Introduction

This chapter includes an introduction, participants, data analysis overview, data analysis, findings, and interpretation. The multiple case studies are analysed. The analysis and discussion are aligned to three research questions**.** The study employed a mixed methods approach, hence qualitative and quantitative data analysis was employed.

4.2 Participants

Four participants that have experience in teaching electric circuits in grade 7 participated in this study. The pseudonyms in the form of participants' numbers are used in this study instead of their real names to ensure confidentiality. The participants are Participant 01 (P01), Participant 02 (P02), Participant 03 (P03) and Participant 04 (P04)**.**

4.3 Data analysis overview

Mertens (2015) states that the mixed methods research's analytical and interpretative parts of it are shaped by the research paradigm and the research design; the mixed methods design also involves parallel qualitative and quantitative analysis. Besides, the mixed methods can also include the transformation of qualitative data to a quantitative form; the conclusion in the pragmatic paradigm is based on qualitative and quantitative data analysis. Even (Clark & Creswell, 2011) also state that analysis of data in mixed methods could be done quantitatively using quantitative methods or qualitatively using qualitative methods or by mixing qualitative and quantitative data and results when answering the research questions.

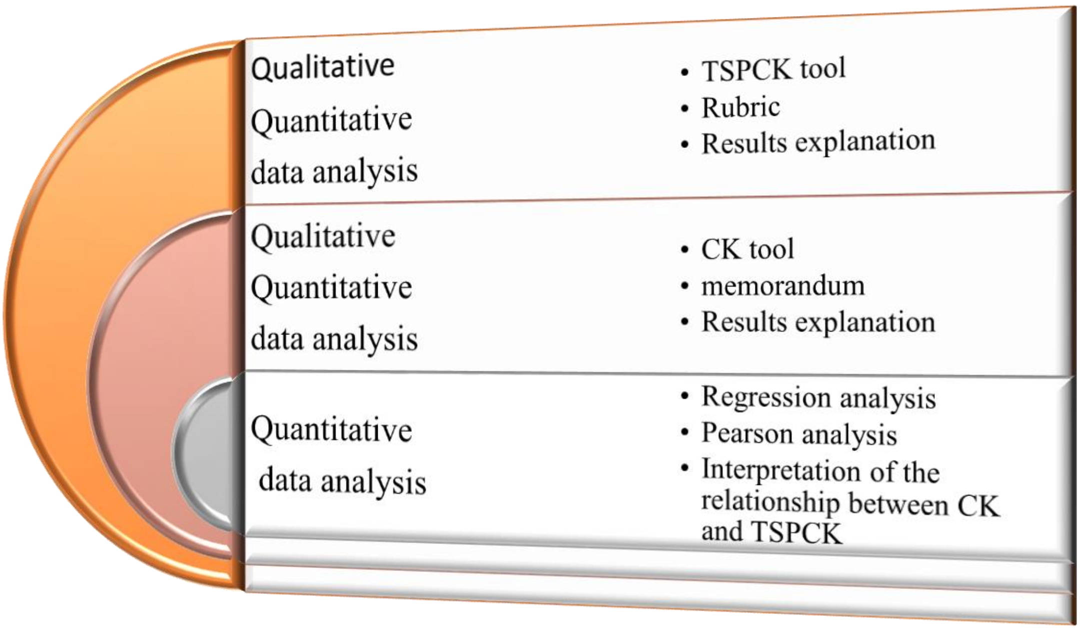
This means in mixed methods design, the qualitative and quantitative data analysis could be done individually or by combining qualitative and quantitative data analysis, and this is also based on the pragmatic paradigm. This is stated by (Clark & Creswell, 2011) by indicating that the conclusion in the pragmatic paradigm is based on qualitative and quantitative data analysis.

This implies that the pragmatic paradigm relates to mixed methods research analysis whereby the qualitative and quantitative analysis is done in parallel.

The mixed methods approach also employs convergent data analysis. Clark and Creswell (2011) highlight that in convergent design, the steps of data analysis include qualitative and quantitative data analysis that takes place in parallel; these data are analysed separately utilising the approaches that are appropriate for qualitative and quantitative analysis to address the research questions; indicate how the results of two databases are compared; stipulate the information that will be compared; analyse quantitative and/or qualitative data to generate the data that will be compared; indicate the comparison; and interpreted how these merged results answer quantitative and qualitative and mixed methods questions.

This study used a mixed methods design to collect data. The convergence method was also used to collect qualitative and quantitative data in parallel. The multiple case studies were analysed to get insight into the teachers' TSPCK. In this study, qualitative and quantitative data were analysed in parallel as depicted in Figure 4.3 considering the three research questions depicted in Figure 3.2.

Figure 4.3 Data analysis



The CK data analysis was conducted to answer research question 1. The CK assessment tool had multiple choice questions to establish the teachers' CK. CK was analysed quantitatively and qualitatively. The memorandum Annexure 5 was used to rate the CK of the teachers quantitatively and qualitatively. The tick was used to indicate the correct answer. One tick equated to one point, and the total was twelve, P01 got three which is 8%, P02 got eight which is 67 %, P03 got seven which is 58% and P04 got eight which is 67% as depicted in depicted in Table 4.1. The qualitative scores for each question were converted to quantitative data (limited -1, basic 2, developing – 3 and exemplary - 4 knowledge) as indicated in Table 4.1. To ensure that the participants do not guess the answers, qualitative analysis of the CK questionnaire involved levels of competency, including not sure, blind guess, confident and completely sure. The level of competency assisted to establish whether the participant knew the response or not, for example, not sure and blind guess denoted that the teacher did not know the answer, and completely sure and confident denoted that the teacher knew the answer.

TSPCK data analysis was conducted to answer research question 2. TSPCK was analysed qualitatively. The rubric was used to rate the teachers' TSPCK qualitatively considering the different knowledge categories as depicted in the TSPCK assessment tool (Annexure 6). The qualitative data analysis was rated using the levels limited, basic, developing, and exemplary.

Research question 3 focused on establishing the correlation between teachers' CK and TSPCK and a comparison was used using Pearson moment correlation and regression relationship. The qualitative analysis of TSPCK was converted to quantitative analysis involving the rating Limitation-1; Basic-2; Developing-3; and Exemplary-4. CK quantitative data and TSPCK quantitative data were compared to establish the correlation.

The Pearson product-moment correlations study the degree, as well as the direction of the relationship concerning the two variables; the variables are measured continuously in terms of ratio or interval. The Pearson relationship is utilised to measure the possible relationship regarding the variables. The correlationship varies from -1.00 to +1, portraying the perfect correlation and in a positive correlation, if one variable increases, the other variable increases (Russel & Purcell, 2009)

The regression relationship of CK and TSPCK was established in this study. Regression studies the relationship between variables, and prediction is the goal of regression; the independent and the dependent variables must be continuous in terms of ratio or interval. It anticipates that one variable will predict another variable; regression is similar to correlation as they work on a linear model (Russel & Purcell, 2009). In this study, this means CK predicts TSPCK even though the relationship is weak. It is not always the case that CK predicts TSPCK.

Cresswell and Cresswell (2018) suggest the plans that could be used to depict/present data analysis, including the number of the participants in a sample who are the respondents and non-respondents; ascertain the method that will be utilised to respond to bias; plan for descriptive analysis; calculate scores when using an instrument; and portray the results in tables or figures. The results in this study were presented in figures and tables. The calculations using Pearsons's product-moment method were done. Figure 4.5 portrays regression illustrating the relationship between CK and TSPCK.

4.4 Analysis and findings

The findings were analysed and discussed according to the research questions. Research question 1 was analysed first, followed by research question 2 and research question 3 last.

4.4. 1 Research question 1: What is the level of grade 7 teachers' content knowledge when teaching electric circuits?

This research question focused on the CK of four grade 7 teachers when teaching electric circuits. Data were collected using the CK assessment tool questionnaire with the questions aligned to different learners' misconceptions.

The results were analysed qualitatively and quantitatively since the study employed the mixed methods approach. For the answer to be regarded as correct, the level of confidence should be confident or completely sure. The correct answer with a confidence level blind guess and a bit unsure indicates limited knowledge.

4.4.1.1 Analysis and findings of CK assessment tool questionnaire

The CK assessment tool analysis and findings regarding the four case studies are provided below. The questions were analysed as follows:

1. Is the charge consumed by the light bulb/lamp when it produces light?

A. Yes, when the charge moves through the filament, friction is produced that generates that heat and the filament emits heat and light.
B. Yes, the charges are produced
C. No, the charge is not conserved, it is transformed into heat and light.
D. No, the charge is not consumed but it is conserved, the charge moves through the filament and creates friction that heats up the filament, and light is emitted.
E. None of the above.

The correct answer is D. The correct answer indicates the knowledge of the misconception of the charge being consumed. The incorrect answer indicates the limited knowledge of this misconception of the charge being consumed.

P01

P01 chose option C which is incorrect, and the level of confidence is a blind guess, therefore this indicates a misunderstanding of the misconception of the charge being consumed.

P02

P02 chose D which is correct, and the participant was confident about the answer, thus this indicates an understanding of the misconception of the charge being consumed.

P03

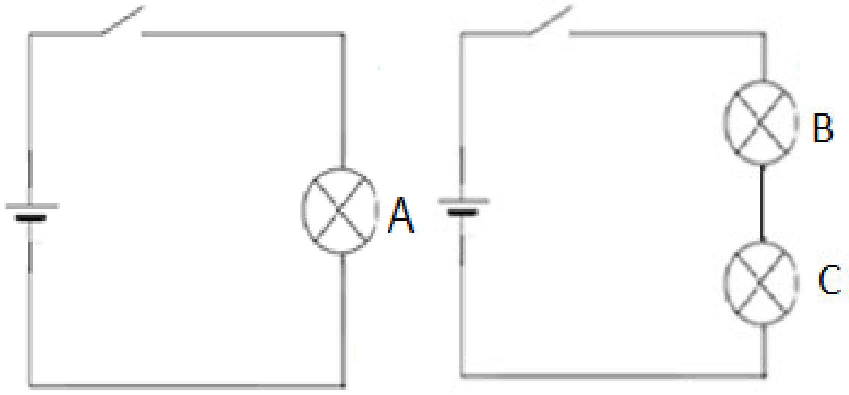
P03 chose option A which is incorrect, and the participant was confident about the answer which indicates the limited knowledge of the misconception of the charge being consumed.

P04

P04 chose option A which is incorrect, and the participant was confident about the answer which denotes the limited knowledge of the misconception of the charge being consumed.

Only P02 out of four participants chose the correct response which is D, and the participant was confident about the answer which is an indication that the participant is possessing the knowledge of the learners' misconception and pre-conception of the charge being consumed. P01, P03 and P04 got incorrect answers, and their confidence levels were blind guessing and confident. This indicates that most participants are experiencing a challenge as far as the misconception of the charge being consumed in an electric circuit is concerned.

2. How is the energy supplied to the bulb/lamp A in circuit 1 changed when the bulb/lamp B is added as indicated in circuits 1 and 2?



Circuit 1 **Circuit 2**

A. Lamp/Bulb A has least energy
B. Lamp/bulb B has least energy.
C. Lamp A and B have least energy.
D. Lamps B and C have least energy.

The correct answer is D. The incorrect answer implies that the participants lack the knowledge of energy supply in circuits. The correct answers imply that they have knowledge of energy supply in an electric circuit.

P01

P01 chose option D which is correct, and the participant was a bit unsure.

P02

P02 chose option B which is incorrect, and the participant was confident about the answer.

P03

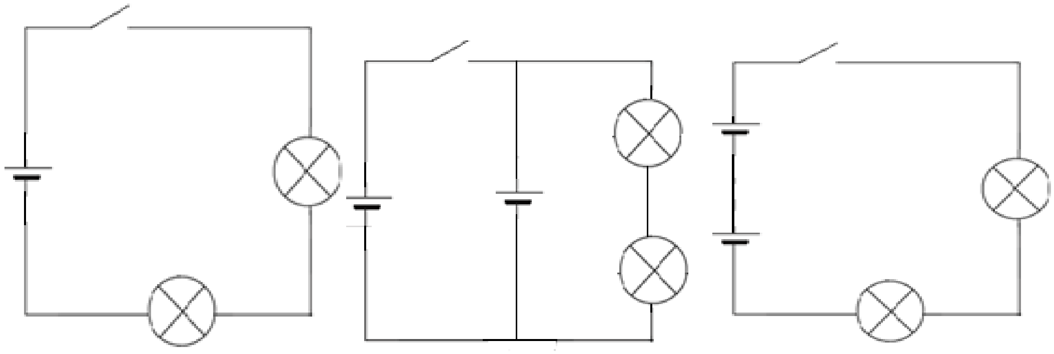
P03 chose option A which is incorrect, and the participant was confident about the answer.

P04

P04 chose option D which is correct, and the participant was confident.

Only P04 got this question correctly and was confident. P01 got it correctly but was a bit unsure which indicates limited knowledge. The other 2 participants (P03 and P02) got the answer incorrectly and were confident about their answers. This indicates that most participants lack the knowledge of the concept of energy supply in an electric circuit.

3. Choose the circuit that has the greatest energy that is supplied to it.



Circuit 1 Circuit 2 circuit 3

A. Circuit 1
B. Circuit 2
C. Circuit 3
D. Circuits 1 and 2
E. Circuits 2 and 3

The correct answer is **C**

P01

P01 chose option B which is incorrect and was confident.

P02

P02 chose option B which is incorrect and was confident.

P03

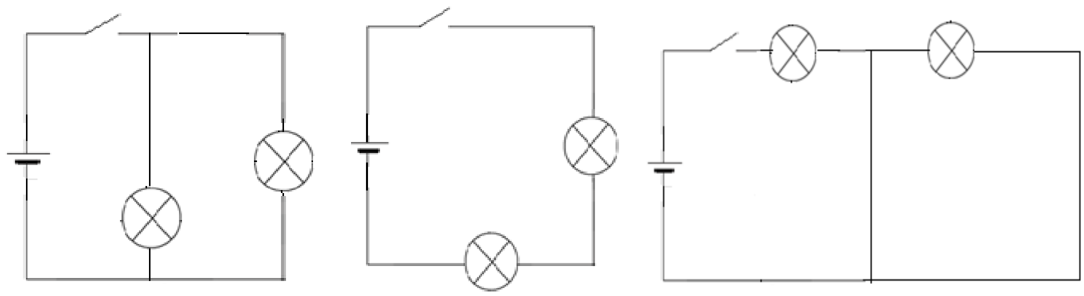
P03 chose option C which is correct and was completely sure about the answer.

P04

P04 chose option C which is correct and was confident.

Two out of four participants (P03 and P04) got the answer correctly, and they were completely sure and confident about the answer respectively which means they possess the knowledge of voltage. However, another half portrayed limited knowledge of voltage in electric circuits. They have the misconception of the voltage in a circuit

4. In the circuit/circuits provided below, identify the circuit/circuits that comprise/s two light bulbs in series with a cell.



Circuit 1 Circuit 2 Circuit 3

A. Circuit 1
B. Circuit 2
C. Circuit 3
D. Circuits 1 and 2
E. Cicuits 1 and 3

The correct answer is **B**

P01

P01 chose option C which is incorrect, and it was a blind guess.

P02

P02 chose option B which is correct and was confident about the answer.

P03

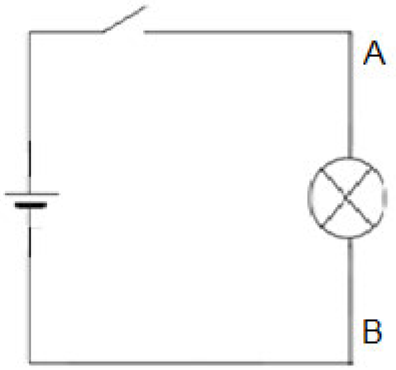
P03 chose option B which is correct and was completely sure about the answer.

P04

P04 chose option B which is correct and was confident about the answer, thus the participant understands the concept of series in the electric circuit arrangement of bulbs.

Three out of four participants answered correctly, and two were confident or completely sure respectively, which indicates that they know the arrangement of bulbs in a circuit. One participant out of four got the answer incorrectly and was blind guessing, which indicates the limited knowledge of the electric circuit arrangement of bulbs.

5. Indicate the point that has the largest current



A. Point B
B. Point A
C. Either point A or point B
D. Neither point A nor point B, the current is the same in point A and Point B.

The correct answer is **D.**

P01

P01 chose option D, which is correct, but blind guessed the answer, which indicates limited knowledge of misconception of the current being consumed.

P02

P02 chose option B, and the answer is incorrect but was confident, which indicates limited knowledge of misconception of the current being consumed.

P03

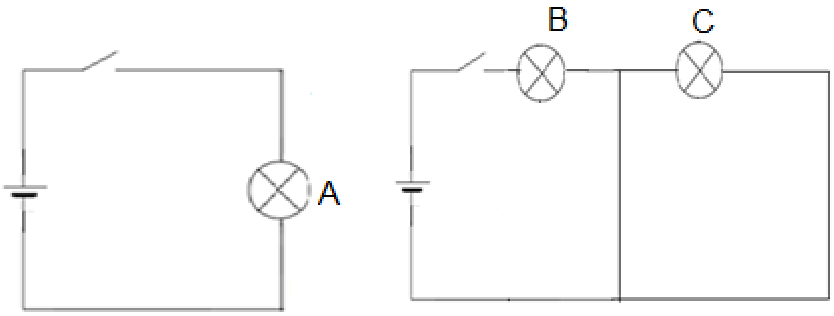
P03 chose option D, which is correct but P03 blind guessed the answer, which indicates limited knowledge of misconception of the current being consumed.

P04

P04 chose option D which is correct. P04 was confident about the answer which indicates a lack of knowledge or misconception of the current being consumed.

Three out of four participants got the answer correctly, P01, P03 and P04. P01 and P03 blind guessed the answers, but P04 was a bit unsure. This indicates that three out of four participants have limited knowledge of misconception of current being consumed. Only one participant possesses the knowledge of the misconception of the current being consumed.

6. Which bulb or lamp will glow if the switches are closed?



A. A only
B. B only
C. A & B only
D. B & C

The correct answer is **C**

P01

P01 chose option A which is incorrect and was confident about the answer. The participant lacks knowledge of the circuit as a whole since the wires resemble a parallel circuit in the second circuit and does not understand that the wires connecting B and C cause lower resistance, hence the current would not be able to reach lamp C. Only A and B will light up.

P02

P02 chose option C which is correct and was confident about the answer. The participant has knowledge of the circuit as a whole since the wires resemble a parallel circuit in the second one and understands that the wires connecting B and C cause lower resistance, hence the current would not be able to reach lamp C. Only A and B will light up.

P03

P03 chose option A which is incorrect and was completely sure. The participant has limited knowledge of the circuit as a whole since the wires resemble a parallel circuit in the second one. The participant did not understand that the wires connecting B and C cause lower resistance, hence the current would not be able to reach lamp C. Only B lights up.

P04

P04 chose option A which is incorrect and was confident about the answer. The participant has limited knowledge of the circuit as a whole since the wires resemble a parallel circuit in the second one. They did not understand that the wires connecting B and C cause lower resistance, hence the current would not be able to reach lamp C. Only B lights up.

Three out of four participants, P01, P03 and P04, chose incorrect responses, and this means the participants have limited knowledge of how the circuit as whole works. Only P02 got it correctly.

7. Why is series wiring of all the lights in the house not recommended?

A. Less charge will be released and the lights will dim

B. If one light fails that would cause all lights to go dark.

C. The current will be stored and the lights will go dark.

The correct answer is **B**

P01

P01 chose option B, which is correct, but blind guessed the answer. This indicates the misunderstanding of open series circuits.

P02

The participant chose option B which is correct but was confident about the answer. This indicates the understanding of open series circuits.

P03

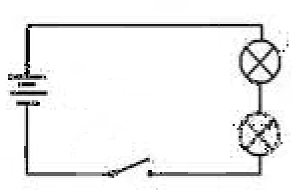
The participant chose option B which is correct and was completely sure about the answer. This indicates the understanding of open series circuits.

P04

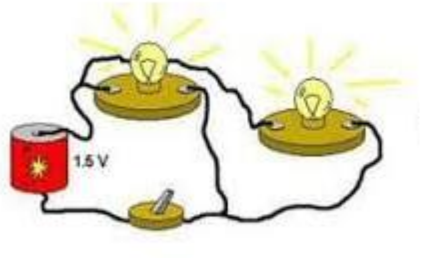
P04 chose option B which is correct and was confident about the answer. This indicates an understanding of a series circuit.

All four out of four participants got the answer correctly by choosing option B. However, P01 blind guessed the answer which indicates limited knowledge of open series circuits. Three participants were either confident or completely sure about the answer. This indicates that three participants understand open series circuits.

8. Choose the schematic diagram that is represented by the circuit diagram that is provided below if the switch is closed. Schematic diagram 1 and 2 are provided.

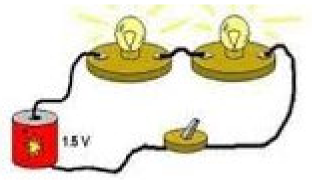


Circuit 1.



https://www.google.com.

Circuit 2.



https://www.google.com.

A. Circuits 1
B. Circuit 2
C. Circuits 1 & 2
D. None of the above.

The correct answer is **B**

P01

P01 chose option B which is correct and was confident about the answer, thus the participant has knowledge of the actual series circuit.

P02

P02 chose option A which is incorrect and was confident about the answer. It shows that the participant has limited knowledge of the actual series circuit.

P03

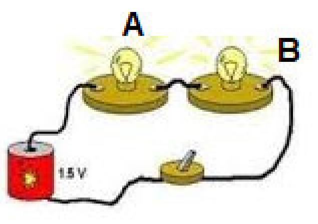
P03 chose option B which is correct and was completely sure about the answer. It shows that the participant has knowledge of the actual series circuit.

P04

P04 chose option B which is correct and was confident. It shows that the participant has knowledge of the actual series circuit.

Three participants out of four **(**P01, P03, P04) chose the correct option, and they were confident or completely sure about the answer. This indicates that they have knowledge of the concept of actual series circuits. Only P02 got it incorrectly which indicates limited knowledge about actual series circuits.

9. The circuit diagram with 2 bulbs is provided below. What will happen to bulb B if bulb A is removed?



https://www.google.com.

A. Bulb will light up.

B. Bulb current will be reduced but still light up.

C. Bulb B current will be increased since there is only one bulb that is consuming the current.
D. The current will not reach light B

The correct answer is **D**

P01

P01 chose option C which is incorrect and was a bit unsure. This indicates the limited knowledge of a broken circuit.

P02

P02 chose option D which is correct and was confident about the answer. This indicates the knowledge of a broken circuit.

P03

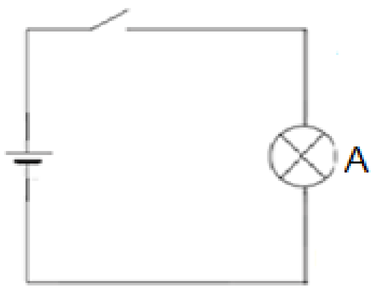
P03 chose option D which is correct and was completely sure about the answer. This indicates the knowledge of a broken circuit.

P04

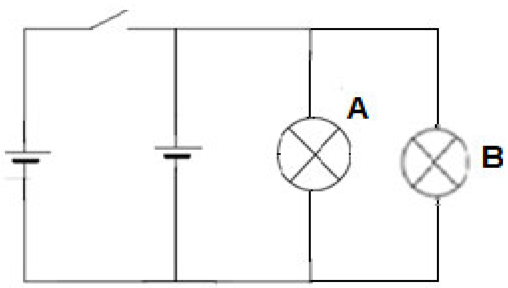
P04 chose option D which is correct and was confident about the answer. This indicates an understanding of a broken circuit.

Three out of four participants, P02, P03 and P04, chose the correct answer and were either completely sure or confident, which indicates knowledge of broken circuits. However, P04 chose D which is correct but was a bit unsure which indicates limited knowledge of the broken circuit.

10. The circuit diagrams are provided below . Identify the bulb/lamp with decreased brightness if bulb A in circuit 1 is compared to bulb A in circuit 2.



Circuit 1



Circuit 2

A. Bulb/lamp A in circuit 1
B. Bulb/lamp A in circuit 2
C. Neither A in circuit 1 nor A in circuit 2, the brighness is the same.

The correct answer is **C**

P01

P01 chose option B which is incorrect. P01 blind guessed the answer. This indicates limited knowledge of voltage in parallel circuits.

P02

P02 chose option C which is correct. P02 was confident of the answer. This indicates knowledge of voltage in parallel circuits.

P03

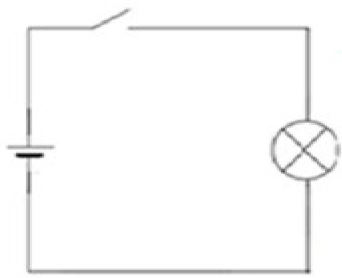
P03 chose option B which is incorrect and was completely sure about the answer. This indicates limited knowledge of voltage in parallel circuits.

P04

P04 chose option B which is incorrect. This indicates limited knowledge of voltage in parallel circuits.

P01, P03 and P04 chose incorrect options. This indicates a misunderstanding of parallel circuits. Only one participant (P02) got the answer correctly and was confident. This indicates knowledge of parallel circuits.

11. If the switch is closed what happens to the resistance of the bulb/lamp in the circuit diagram below?



A. The resistance decreases.

B. The resistance increases.

C. The resistance of the bulb/lamp remains the same.

D. There is no resistance.

The correct answer is **B**

P01

P01 chose option C which is incorrect and was a bit unsure. This indicates a misunderstanding of resistance.

P02

P02 chose option B which is correct and was confident. This indicates an understanding of resistance.

P03

P03 chose option B which is correct and was confident This indicates an understanding of resistance.

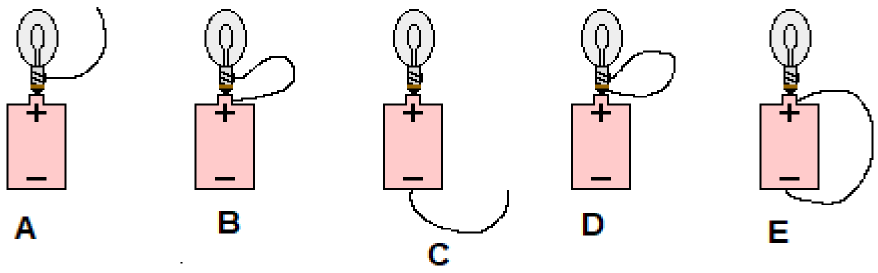
P04

The P04 chose option A which is incorrect and was confident. This indicates limited knowledge of resistance in circuits.

Half of the participants, P02 and P03, chose option B which is correct, and they were confident about the answer. This indicates an understanding of resistance in circuits.

P04 chose option A and was confident which is incorrect thus indicating a misunderstanding of resistance. P01 chose C and was a bit unsure about the answer. This indicates a misunderstanding of resistance.

12. Identify the circuit or circuits with the bulb that will light up.



https://www.google.com.

A. Circuits A&B
B. Circuits C&D
C. Circuits B&D
D. Circuit E
E. All bulbs will not light up

The correct answer is **E**

P01

P01 chose option E which is correct and was confident about the answer, which indicates the knowledge of the sink model.

P02

P02 chose option E which is correct and was confident, which indicates the knowledge of the sink model.

P03

P03 chose option E which is correct and was completely sure, which indicates the knowledge of the sink model.

P04

P04 chose option E which is correct and was confident, which indicates the knowledge of the sink model.

Four out of four participants chose the correct option, and they were completely sure or confident, which is an indication that they possess knowledge of the sink model.

The memorandum was used to mark the CK assessment tool questionnaire and the summary of analysis and findings (qualitative and quantitative) are summarised in Table 4.1 The table also indicates the misconceptions that are aligned to each question.

Table 4.1 CK Qualitative and Quantitative Analysis and Findings

Question No.	Misconception	Correct Answer	P01	CL	P02	CL	P03	CL	P04	CL	No. of participants with correct answers.	Percentage (%)
1	The charge is consumed	D	C X	BG	D √	C	A X	C	A X	C	1	25%
2	Energy supply in a circuit.	D	D √	ABUX	BX	C	A X	C	D √	C	1	25%
3	Interchangeability of terms: voltage, current, power, charges energy used as one property	C	B X	C	B X	C	C √	CS	C √	C	2	50%
4	Arrangement of bulbs in electric circuits.	B	C X	BG	B √	C	B √	CS	B √	C	3	75%

5	Current is consumed	D	D √	BGX	B X	C	D √	BGX	D √	C	3	50%
6	Circuit as a whole	C	A X	C	C √	C	A X	CS	A X	C	1	25%
7	Open or broken circuit	B	A X	BG	B √	C	B √	CS	B √	C	3	75%
8	Series circuit or arrangement of bulbs	B	B √	C	AX	C	B √	CS	B √	C	3	75%
9	Broken circuit/series circuit	D	C X	ABU	D √	C	D √	CS	D√	C	3	75%
10	Voltage in parallel circuits.	C	B X	BG	C √	C	B X	CS	B X	C	1	25%
11	Interchangeability of terms resistance and current.	B	C X	BG	B √	C	B √	C	AX	C	2	50%
12	Unipolar model	E	E √	C	E √	C	E √	CS	E √	C	4	100%
Total		12	1		8		7		8			
%			8%		67%		58%		67%			Average: 54%

Quantitative analysis levels	1	3	2	3	2
Qualitative Analysis levels	Limited	Developing	Basic	Developing	Basic

Note. In four questions, 1 participant got the answer correctly which is 25%. In three questions, 3 participants got the answer correctly which is 50%. In one question, 4 participants got the answer correctly which is 100%. **CL=Confidence level; C=Confident; BG=Blind guess; CS=Completely sure; ABU=A bit unsure.** The participant who obtained (√) for the correct answer and (X) for CL meaning the answer is regarded as incorrect since the CL is either BG or ABU.

Table 4. 2 depicts the overall analysis of qualitative and quantitative CK. Qualitative data was also converted to quantitative data.

Table 4.2 Overall CK Qualitative and Quantitative Analysis

	Quantitative analysis	Qualitative analysis	Qualitative to quantitative analysis
Participants	Score	Qualitative rating	Quantitative rating
P01	02	Limited	1
P02	08	Developing	3
P03	07	Basic	2
P04	08	Developing	3
Overall		Basic	2
Average	6		

Notes. 50% of participants are at level 3; 50% of participants are below level 3. **Limited=1. Basic=2. Developing=3. Exemplary=4.** Initially qualitative and quantitative data were analysed separately. The qualitative data was then converted to quantitative data. The total score for CK is 12.

4.4.2 Research question 2: What is the nature of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits?

The TSPCK assessment tool questionnaire was used to collect qualitative data. The questions in the questionnaire were aligned to different TSPCK categories (see TSPCK categories in Figure 3.5.2.2). The findings for research question 2 emanated from the analysis of different TSPCK categories (Figure 3.5.2.2). The categories of knowledge serve as suitable instruments to capture the teachers' TSPCK knowledge that is required to answer research question 2. The rubric was used to rate the teachers' TSPCK knowledge.

4.4.2.1 Analysis of the TSPCK assessment tool questionnaire

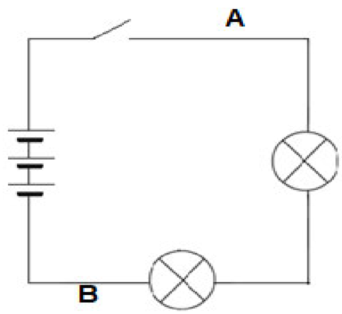
The results were analysed qualitatively and converted to quantitative data since the study employed a mixed methods approach. Initially, qualitative analysis was employed to analyse data. The analysis was based on the different categories of TSPCK as depicted in Figure 3.5.2.2 The levels are Limited, Basic, Developmental and Exemplary. If the participant is at the basic level, it means the TSPCK is basic; limited means the TSPCK is limited; developing means the TSPCK is developing and exemplary means the TSPCK is exemplary.

4.4.2.1.1 Category 1 – Learner's prior knowledge and misconceptions

In this category, the analysis was based on the teachers' knowledge of learner prior knowledge and misconceptions**.** The questions were structured to reveal this knowledge. The individual participant's responses were analysed, and the ratings were indicated. The individual findings were combined to ascertain TSPCK all participants. This category comprises two questions. **Question 1.1** focuses on the knowledge of the teacher about the learner prior knowledge and the misconception related to the current consumption/weakening model/attenuation model. To answer this question correctly, the participants should understand the concepts, including battery, electrons, electric field, and electric current.

The most relevant response is Response C.

Question 1.1 Study the circuit diagram below and answer the following question.



The following responses were provided by the learners if the electric circuit is **closed**. These answers were either correct or incorrect. The question and responses from the teacher are given below.

You are required to choose the feedback or comment to learners' responses that you would probably use when teaching electric circuits and give the reason for their choice.

(i) The current in **B** is smaller than in **A.**
(ii) The current **A** is smaller than in **B**
(iii)The current in **A** is equal to **B**

Feedback/comments on leaners' responses

Choose the comment/feedback on the learners' responses (i) or (ii) or (iii)] that you would give to the learner and provide the reason/s in the space provided below.

Response A: The correct answer is (iii). The current does not split or divide since this is a series circuit. The current strength is the same throughout the circuit.

Response B: The correct answer is (iii). The rate at which the charge flows is called the current. It involves the movement of the electric charge carriers called electrons. The electrons move around the circuit, and they do not vanish in the electric circuit.

Response C: The correct answer is (iii). The rate at which the charge flows in an electric circuit is called a current. In an electric circuit, there is a flow of charge. The charge moves by means of a conductor. The charged particles move because of electric field that is produced by the battery and the particles that are charged are in the same electric field. The charge is the same across the electric circuit.

Response D: None of the above

Table 4.3 depicts the participants' responses to category 1 question 1.1.

Table 4.3 Category 1 Learner Prior Knowledge and Misconceptions Participants' Responses 1.1

Participants	P01	P02	P03	P04
Responses	Select your response from the responses provided (A or B or C or D) and provide a reason for your choice in detail. Your choice: A The reason for your choice: WHEN ELECTICAL COMPONENTS ARE CONNECTED IN SERIES, THEY FOLLOW ONE ANOTHER AND THE CURRENT PASSES THROUGH EACH COMPONENTS WHEN ELECTRICAL COMPONENTS ARE CONNECTED IN PARALLEL, THEY BANCHOUT AND THE ELECTRIC CURRENT SPLITS SO THAT ONLY ~~ONE~~ PART OF THE CURRENT PASSES THROUGH	Your choice: (iii) The reason for your choice: The current does not split or divide since this is a series circuit. The current strength is the same thoughout the circuit.	Select your response from the responses provided (A or B or C or D) and provide a reason for your choice in detail. Your choice: RESPONSE A The reason for your choice: At this level of grade 7, I recommend response A, as the simple and straight forward answer that can be easy to be understood by learner. Response B and C seem to be more detailed for them at their level. They will get confused when we speak of charge carries and electrons As a teacher, When I teach this grade I use to relate to what was going on at my age of the same grade. I believe my mental capacity was not sufficient to absorb too much information.	***Your choice C*** ***The Reason for your choice.*** *feedback C is the most suitable response of them all. 1. because response (iii) is the correct one 2. because it explains in greater depth, and it makes it clear as to why the learner is correct and it gives them information that will make them be able to know what to look for when responding to such a question. 3. in sentence*

		number 3, i think the teacher should have explained in the same sentence in terms of when does a circuit have a flow of charges i.e in a closed circuit with an energy source, there is a flow of charge

The findings for Question 1.1 are presented according to the relevancy with regards to the descriptors on the rubric. Table 4.4 depicts the analysis of findings for Question 1.1.

Table 4. 4 Category 1 Learner's Prior Knowledge and Misconceptions Analysis, Findings and Ratings of question 1.1

	Individual findings				Combined findings
Participant	P01	P02	P03	P04	
Rating	Limited	Limited	Limited	Limited	Limited
Findings	The participant chose response A which is less relevant as compared to Response C.	The participant chose (iii) instead of A, B, C and D as indicated by the instruction, and response A is less relevant as compared to C.	P04 chose Response A which is less relevant as compared to Response C which is a more relevant option.	P04 chose Response C which is the most relevant option.	P04 chose Response C which is the most relevant option. The other participants chose the options that are less relevant as compared to response C
Explanation of pre concepts	The explanation of concepts was related to the flow of current considering the arrangement of components in a	The explanation of pre-concepts is more of the duplication of what is provided in that response option which is	There was no explanation of the pre-concept.	There was no explanation of pre-concepts. The participant duplicated what was in Response C	The explanations of pre-concepts were either not indicated or not related to the most appropriate answer.

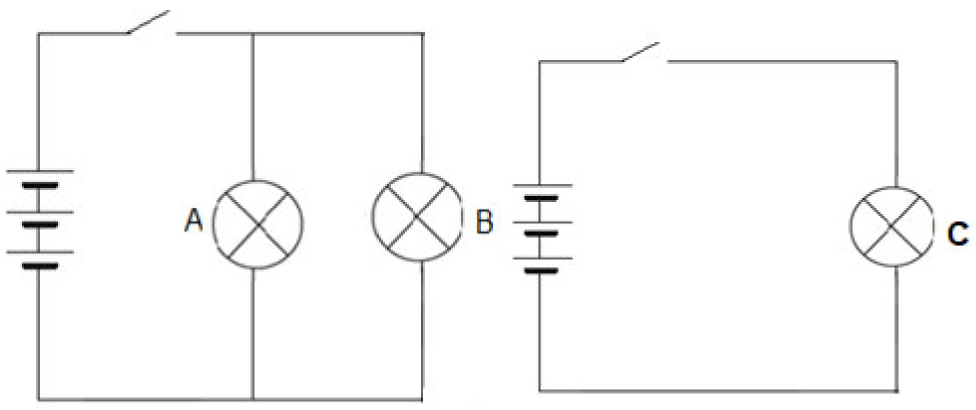
	circuit instead of including the concept, for instance, the electrons, current, and electric field, and electric charge.	splitting or dividing the current since this is a series circuit. The explanation does not include the concepts, for example, electrons, current, electric field, and electric charge.		In the explanation, the participant did not indicate the pre-concepts, including electrons, electric current, electric field, and charge.	
Reasons for selecting the response	The reason for selecting the response is not indicated according to the explanation.	The reason was related to dividing and splitting of the current since the circuit is in series, which is just a duplication of what was	The reason for choosing response A cited is that A is easy for grade 7 learners. Also, the reason relates it to mental capacity of the teacher when the teacher was in the same grade	The reason that was provided by the participant included that Response C provides greater or deeper explanation which clarifies reason of being correct by the learners.	The reasons for selecting the answer were either not related to the most relevant response or not indicated.

		provided in a response option.	which was not sufficient to grasp too much information. The teacher also cites that the learners are confused by charge and electrons, but the teacher did not elaborate on those misconceptions.	The participant did not elaborate.	
Misconception	The misconceptions were not indicated. The prior knowledge and misconceptions that could have been pointed out include:	The misconceptions were not indicated The prior knowledge and misconceptions that could have been pointed out include:	The misconception was indicated as charge carriers and electrons. In this response, the charge carriers were treated as different misconceptions, yet the charge carriers are electrons.	The prior knowledge or misconceptions are not indicated The prior knowledge and misconceptions that could have been pointed out include: ○ the current/charge is used up or attenuation model	The misconceptions were not indicated.

	○ the current/charge is used up or attenuation model ○ confusing energy and current/charge	○ the current/charge is used up or attenuation model ○ confusing energy and current/charge	The prior knowledge and misconceptions that could have been pointed out include: ○ the current/charge is used up or attenuation model ○ confusing energy and current/charge.	○ confusing energy and current/charge. There is no mitigation of misconceptions.	
Mitigation of misconception	The mitigation of misconception was not indicated.	The mitigation of misconception was not indicated.	The mitigation of misconception was not indicated.	The mitigation of misconception was not indicated.	The mitigation of misconceptions was not indicated.

Note. The participants portrayed limited knowledge of learner's misconceptions and prior knowledge.

1.2 A grade 7 Technology learner was asked to compare the brightness of the lamp/bulb A in circuit 1 to lamp/bulb C in circuit 2 if the switches are closed and the lamps or bulbs are identical.



Circuit 1 **Circuit 2**

(i) The lamp/bulb A is brighter in circuit 1 than the lamp/bulb C in circuit 2.

(ii) The lamp/bulb C is brighter in circuit 2 than the lamp/bulb A in circuit 1.

(iii)The brightness of the lamp/bulb A in circuit 1 is the same as in lamp/bulb C in circuit 2

Feedback/ comments on leaners responses.

Response A: The number of lamps or bulbs in circuit 1 does not determine the brightness of the lamp or bulb in circuit 2. The brightness of the lamp is determined by the amount of current that is flowing through the lamp or bulb. In circuit 1, the brightness of the bulb A does not imply that the lamp or bulb will glow brighter than a bulb or lamp C in circuit 2. In circuit 1, the current is divided since the lamps are connected in parallel. The resistance of the lamps is halved, and the current is doubled hence the current is the same in parallel connection circuit 1 as compared to the brightness of the bulb or lamp in circuit 2. The current that is flowing through parallel branches circuit 1 is the same through each bulb hence the brightness is the same as compared to the brightness of the bulb circuit 2.

RESPONSE B: The bulbs are the same. The brightness of the bulbs is determined by how they change energy. In circuit 1 the current is doubled and halved in parallel connection hence the similar amount of the current is available to be changed. The resistance in circuit 2 is half the overall resistance.

RESPONSE C: In circuit 1, the bulbs are connected in parallel. There is division of current in parallel circuits. The resistance in bulbs or lamps is the same in parallel circuits hence the division of current is the same. The resistance is the same in parallel circuits. The two bulbs in parallel divide the resistance into halves and the current doubles, and the current is halved again at the parallel connections. The brightness of the lamps or bulbs is the same.

RESPONSE D: None of the above.

Question 1.2 illustrates their understanding of the learner prior knowledge and misconceptions related to the brightness of the bulb/lamp when connected in series and parallel considering the power supply. The most relevant answer is B. Examples of misconceptions include a battery as a source of constant power supply; the bulbs in series produce more brightness all the time; parallel bulbs are brighter than series circuits all the time, as well as the focus in a circuit being on the number of components like bulbs irrespective of how they are connected. The participants could not choose the most relevant option. This is an indication of limited knowledge of learner prior knowledge and misconceptions. Table 4.5 illustrates responses and ratings of question 1.2 of category 1

Table 4.5 Category 1 Learner's Prior Knowledge and Misconceptions Responses and Rating for Question 1.2

Participants	P01	P02	P03	P04
Rating	Limited	Limited	Limited	Limited
Responses	Your choice: C The reason for your choice: Because when electrica components are connecteo whether parallel or series but the current passes through each component	Your choice: C The reason for your choice: The bulbs are connected in parallel. There is division of current in parallel circuit. The resistance in bulbs or lamps is the same in paralel hance the division of current is the same. The resistance is the same in parallel circuits. The 2 bulbs in parallel divids the resistance into halves and the current double. The current in halved again at the parallel connections. The brightness of the lamps or bulbs is the same.	Your choice: RESPONSE C The reason for your choice: -In circuit 1 the battery supplies the same amount of voltage as the battery in circuit 2, because in circuit 1 there are two bulbs the current will be divided. -This will make bulb A in circuit 1 to be less brighter than Bulb C in circuit 2. -Remember that each bulb brings it resistance in a circuit, hence the more resistance the less current flowing in a circuit.	Your choice: response D The reason for your choice: neither of the feedbacks provided by the educators explain which of the response is correct for the question. in circuit 1, the voltage across each of the components is the same and the total current is the sum of the currents through each component. in parallel circuit, the current is divided. in circuit 2, the current through each component is the same and the voltage across the circuit is the sum of voltages across each component bulb C in circuit 2 will be brighter than bulb A in circuit 1

The analysis, findings, interpretation, and rating for question 1.2 are illustrated in Table 4.6.

Table 4.6 Category 1 Learner Prior Knowledge and Misconceptions Analysis, Findings, Interpretation and Rating for Question 1.

	Individual participant findings				Combined findings
Participant	P01	P02	P03	P04	All participants
Rating	Limited	Limited	Limited	Limited	Limited
Responses	P01 chose Response C related to circuits.	P02 chose Response C related to circuits.	P03 chose Response C related to circuits. .	P04 chose Response D related to circuits.	All the participants chose Response C which is less appropriate as compared to Response B. Response B is more relevant because it includes the issue of power/energy which clarifies the issue of brightness, yet Response C only deals with current and resistance. Response D is irrelevant because it does not explain the concepts related to the brightness of the bulb.

Explanation of pre concepts	The explanation was about the connection of components and the current without elaborating. The explanation does not indicate the bulb brightness rule conception related to parallel and series circuits	The explanation is merely a repetition of Response C. The explanation does not indicate the bulb brightness rule conception related to parallel and series circuits.	The explanation included the battery which provides voltage, division of current in circuit 2 and less brightness in bulb A as compared to bulb C. The more resistance, the less the current. This explanation shows the misconception related to the brightness of the bulb rule. The explanation does not indicate the bulb brightness rule conception related to parallel and series circuits.	The explanation indicates that bulb C will be brighter than C, which is correct, but the explanation is unclear with regards to how this happens. The explanation does not indicate the bulb brightness rule conception related to parallel and series circuits.	The explanation does not indicate the bulb brightness rule conception related to parallel and series circuits. The explanations of P01, P02 and P03 did not incorporate the brightness rule conception in parallel and series circuits. P04 was able to note correctly that bulb C is brighter than bulb A even though the response that was chosen was not the most relevant.

Reasons for selecting the response	The reason for choosing Response C is limited to the current passing through each component in circuits without providing more explanation	The reason for choosing Response C is merely a repetition of Response C.	The explanation included the battery which provides voltage, division of current in circuit 2 and less brightness in bulb A as compared to bulb C. The more resistance, the less current. The focus was only on current and resistance without further deliberation.	The reason for choosing Response D includes that there is no correct response, as the voltage across each component is the same since C is brighter than A.	The reasons that are provided are unrelated to the brightness rule conception.
Misconception	The misconceptions are not indicated. Examples of misconceptions that could be included: ▪ Power supply as a constant	The misconceptions are not indicated. Examples of misconceptions that could be included:	The misconceptions are not indicated. Examples of misconceptions that could be included:	The misconceptions are not indicated. Examples of misconceptions that could be included:	The misconceptions were not indicated by all participants which is an indication of limited knowledge in this regard.

	source of current. ▪ Bulbs in series produce more brightness all the time. ▪ The parallel bulbs light up brighter than series bulbs. ▪ The focus is on the number of components, e.g., bulbs irrespective of how they are connected.	▪ Power supply as a constant source of current. ▪ Bulbs in series produce more brightness all the time. ▪ The parallel bulbs light up brighter than the series bulbs. ▪ The focus is on the number of components, e.g., bulbs irrespective of how they are connected.	▪ Power supply as a constant source of current. ▪ Bulbs in series produce more brightness all the time. ▪ The parallel bulbs light up brighter than series bulbs. ▪ The focus is on the number of components, e.g., bulbs irrespective of how they are connected.	▪ Power supply as a constant source of current. ▪ Bulbs in series produce more brightness all the time. ▪ The parallel bulbs light up brighter than series bulbs. ▪ The focus is on the number of components, e. g., bulbs irrespective of how they are connected	
Mitigation of misconception	Mitigation of misconception is not indicated.	Mitigation of misconception is not indicated.	Mitigation of misconception is not indicated.	Mitigation of misconception is not indicated.	Mitigation of misconception is not indicated.

Table 4.7 illustrates the overall rating of questions 1.1-1.2

Table 4.7 Overall Rating of Category Learner's Prior Knowledge and Misconceptions

No.	P01	P02	P03	P04	Overall rating Limited
1.1	Limited	Limited	Limited	Limited	Limited

4.4.2.1.2 Category: 2 –Curriculum saliency

Category 2: curriculum saliency consists of four questions 2.1, 2.2, 2.3 and 2.4 that were analysed.

2.1 The content and concepts regarding the electric circuits are provided below. Choose and rank the three concepts that you consider basic and central concepts when teaching electric circuits.

(i) Closed and open circuits.

(ii) The net flow of charge is called an electric current.

(iii) The circuit in which the electrons flow in one pathway is called a series circuit.

(iv) The current flows through each component in a series circuit.

(v) In parallel circuits the current is divided.

(vi) The electric circuit materials provide the charged particles if the electric current is available.

(vii) The electric energy is supplied by the battery and the components that utilise the current include buzzers, bulbs/lamps, and conductor.

(viii) The battery generates an electric field in the materials that form the circuit. The electric field makes the current flow.

(ix) If the current is available in a circuit the energy flows from the battery to the external circuit.

(x) An electric circuit is the path for transmitting electric current.

(xi) An electric circuit is a system in which the transformation in one part can impact other parts.

The big ideas are as follows: -

1. An electric circuit is a system in which the transformation in one part can impact other part.
2. The net flow of charge is called an electric current.
3. The battery generates an electric field in the materials that form the circuit. The electric field makes the current flow.

All participants could not identify the big ideas. This indicates that the participants have limited knowledge of big ideas in electric circuits. The rating, analysis, interpretation, and findings of category 1 question 2.1 are depicted in Table 4.8

Table 4.8 Curriculum Saliency Analysis and Findings for Question 2.1

Participants	P01	P02	P03	P04
Rating	Basic	Limited	Limited	Limited
Responses	CONCEPT Concept 1 (vi) Concept 2 (ix) Concept 3 (vii)	CONCEPT Concept 1 (i) Concept 2 (v) Concept 3 (iv)	CONCEPT Concept 1 The electric circuit is the path for transmitting electric current. Concept 2 -The current flows through each component in series circuits Concept 3 -In parallel circuits the current is divided.	CONCEPT Concept 1 (xii) The electric circuit is the path for transmitting electric current. Concept 2 (xiii) Closed and open circuits. Concept 3 (xiv) The electric current energy is supplied by the battery and the components that utilize the current include buzzers, bulbs/lamps and conductor.

Findings	▪ There is no big idea that was identified. ▪ Concept 1 is not a big idea. ▪ Concept 2 is not a big idea. ▪ Concept is not a big idea. ▪ The reason for ranking it number 3 is not indicated.	▪ The concepts that were provided by the participants are not big ideas, hence the sequence is irrelevant. ▪ Concept 1 is not a big idea. ▪ Concept 2 is not a big idea. ▪ Concept 3 is not a big idea. ▪ The reason for. Choosing ideas is not provided.	▪ There is no big idea that is provided by the participants. ▪ Concept 1 is not a big idea. ▪ Concept 2 is not a big idea. ▪ Concept 3 is not a big idea. ▪ The reason for selecting that idea is provided, but there is no evidence related to linking it with other concepts.	▪ There is no big idea that was identified by the participants. ▪ Concept 1 is not a big idea ▪ Concept 2 is not a big idea. ▪ Concept 3 is not a big idea ▪ The reasons for choosing the big ideas were not provided.

2. 2 Provide the sequence you would use to teach the concepts you have chosen in 2.1 and the reasons for choosing that sequence.

Question 2.2 required the participants to sequence the three basic and central concepts (lofty ideas) from the list that was provided when teaching electric circuits. The possible sequence is provided below, and they were required to provide the reasons.

- Concept 1. (xi) Electric circuit is a system in which the transformation in one part can impact other parts.
- Concept 2. (i) The net flow of charge is called the electric current.
- Concept 3. (viii) The battery generates an electric field in the materials that form the circuit. The electric field makes the current flow.

In all responses, the sequence was impossible since the big ideas were not provided. This indicates the limited knowledge of sequencing the big ideas of electric circuits.

Table 4.9 illustrates the analysis, findings, and ratings for question 2.2.

Table 4.9 Category 2 Curriculum Saliency Analysis, Findings and Ratings of Question 2.2

Participants	P01	P02	P03	P04
Rating	Limited	Limited	Limited	Limited
	2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explan also include other subordinate concepts. The electric circuit material the charged particles of the current is available and w the net flow of the charge electric circuit - If the current is available circuit the energy flows from battery to the external circui we know that electric circ a system in which the trans in one part can impact other - The electric current energy is supplied by the battery and the	Learning about open and closed circuits gives you a better under standing of how circuit work and how to properly analyse them After you understand how circuit work, You move to different types of circuit. A series circuit is the simplest way to start off with learning about how current flows. A series circuit onl has one path through which current can flow that makes it eas to teach as the learner would only have to focus on one path rather than multiple path which makes it difficult to understo After you have a basic understanding of open/closed circuits, You move on to how current is divided in parallel circuits. Paralle circuits are similar to series circuits, They are just connected differently. It is best to learn about how current flows throug each component in a series circuit because you have a better	2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also include other subordinate concepts. Before teaching a learner it is very important to make them understand when we speak of electric circuit, series, circuit and parallel circuit. Remember to use scaffolding method.	2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also include other subordinate concepts. the concepts above interrelate with one another, for example, you can not teach learners what provides the electric circuit with energy having not explained what an electric circuit is, in fact. you first should teach what and electric circuit is, closed and open circuits, what supplies the circuit with energy, the two different kinds of circuits i.e parallel and series circuits, the differences and similarities in terms of their make and in terms of how they work. the concept o current and resistance and the relationship between them in both series and parallel circuits.
Findings	▪ The big idea of a cell providing energy was indicated, but the sequence was not appropriate since other ideas are not big ideas.	• The concepts that are provided are not big ideas, hence the sequence was irrelevant.	▪ The ideas that were provided were not big ideas, hence the sequence was irrelevant.	▪ The ideas that were provided are not the big ideas, hence the sequence was irrelevant.

2. 3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also includes other subordinate concepts. Table 4.10 illustrates the responses, analysis, findings, and ratings for question 2..

Table 4.10 Category 2 Curriculum Saliency Responses, Analysis, Findings and Ratings for Question 2.3

Participant	P01	P02	P03	P04
Rating	Limited	Limited	Limited	Limited
Responses	2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also include other subordinate concepts. The electric circuit materials [illegible] the charged particles if the ele[illegible] current is available and we [illegible] the net flow of the charge [illegible] electric circuit. -If the current is available i[illegible] circuit the energy flows from [illegible] battery to the external circuit. We know that electric circui[illegible] a system in which the transfor[illegible] in one part can impact other p[illegible] -The electric current energy supplied by the battery and	2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also include other subordinate concepts. Learning about open and closed circuits gives you a better under standing of how circuit work and how to properly analyse them After you understand how circuit work, You move to different types of circuit. A series circuit is the simplest way to start off with learning about how current flows. A series circuit onl. has one path through which current can flow that makes it eas to teach as the learner would only have to focus on one path rather than multiple path which makes it difficult to understo After you have a basic understanding of open/closed circuits, You move on to how current is divided in parallel circuits. Paral circuits are similar to series circuits, They are just connected differently. It is best to learn about how current flows throug each component in a series circuit because you have a better	2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also include other subordinate concepts. . Before teaching a learner it is very important to make them understand when we speak of electric circuit, series, circuit and parallel circuit. . Remember to use scaffolding method.	\

	components that utilize the current include buzzers, bulbs lamps and conductor. The battery generates an electric fie in the materials that form the circuit. The electric field make the current to flow.	understanding of how current flows and move on to more challenging circuit and the different types of circuit in open and closed circuits I would use examples such as string of electricity lights that don not work if one bulb goes out (open circuit) and how when you have a video camera directly conne to a TV on the property that shows images from the video camera (closed circuit) for how current flows through eac component in a series circuit I would use freezers and Refridgerators as examples and for how current is divi in a parallel circuit i would use car headlight and street l as examples.		2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also include other subordinate concepts. the concepts above interrelate with one another, for example, you can not teach learners what provides the electric circuit with energy having not explained what an electric circuit is, in fact. you first should teach what and electric circuit is, closed and open circuits, what supplies the circuit with energy, the two different kinds of circuits i.e parallel and series circuits, the differences and similarities in terms of their make and in terms of how they work. the concept of current and resistance and the relationship between them in both series and parallel circuits. 2.3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also include other subordinate concepts. the concepts above interrelate with one another, for example, you can not teach learners what provides the electric circuit with energy having not explained what an electric circuit is, in fact. you first should teach what and electric circuit is, closed and open circuits, what supplies the circuit with energy, the two different kinds of circuits i.e parallel and series circuits, the differences and similarities in terms of their make and in terms of how they work. the concept of current and resistance and the relationship between them in both series and parallel circuits.
Findings	▪ The explanation is just a repetition of the concepts that are provided in the question. ▪ There is no interrelation between	▪ There is no interrelation between big ideas and subordinate ideas since the ideas that were identified were not big ideas.	▪ There is no evidence of the explanation of the interrelationship of big ideas with other subordinate ideas since big ideas were not identified.	▪ Some subordinate concepts were highlighted, but there was no in-depth explanation in terms of how these subordinate concepts interrelate with big ideas.

extensive ideas and subordinate ideas since the big ideas were not identified.	▪ Subordinate ideas were indicated without an explanation of the interrelation with big ideas

In this study, only P04 provided subordinate ideas without linking them to big ideas. There was no evidence of the link between the big ideas and subordinate ideas. The other ideas that were regarded subordinate included what supplies the circuit with energy, electric circuit and current which were not subordinate ideas at all. This is an indication that the participants have limited knowledge of curriculum saliency.

2.4 Why is it important for learners to learn electric circuits?

In this question, the participants were expected to provide the importance of learning electric circuits. Table 4.11 presents category 2 curriculum saliency analysis, findings, and ratings for question 2.4. Some participants could identify the importance of electric circuits in our daily lives, but their knowledge is basic.

Table 4.11 Category 2 Curriculum Saliency Analysis, Findings, Interpretation and Ratings of Question 2.4

Participants	P01	P02	P03	P04
Rating	Limited	Developing	Limited	Limited
Responses	2.4 Why is it important for the learners to learn electric circuits? I THINK SO THAT THEY WILL BE HELPFULLY IN THEIR HOME, SO THAT THEY WILL BE AWARE OF DANGEROUS OF ELECTRICITY IN ELECTIC CONDUCTOR, INSULATOR ETC.	2.4 Why is it important for the learners to learn electric circuits? To know how electricity works in appliances. How it is connected to appliances. To know the dangers of using electricity wrongly. To know how electrical energy is transferred from its source. They will also understand that we use circuit to solve problems in our daily lives to solve problems and satisfy needs that require energy. Examples of everyday problems are traffic light, alarms, street lights, electric gates and electric toys. Learners will also know why wires are insulated and the dangers of using an insulated wires at any connections.	2.4 Why is it important for the learners to learn electric circuits? Electric Circuits - is a practical and a daily application activity, therefoe I trust that it easy for them to understand it.	2.4 Why is it important for the learners to learn electric circuits? Electric Circuits - is a practical and a daily application activity, therefoe I trust that it easy for them to understand it.
Findings	▪ Only the issues of safety (related to conductors) are indicated as the importance of teaching electricity. ▪ The issues of electric circuit providing energy is omitted.	▪ The important related dangers of electricity are indicated. ▪ The importance of knowledge of how electrical energy is changed from its source is omitted.	▪ Importance of using electric circuits is not evident.	The examples are provided in which the electric circuits are used, for instance, in robotics and appliances but the explanation that relates to how the electric circuits contribute to the

▪ The examples where electric circuits are used is omitted.	▪ Energy satisfies some needs like traffic lights, alarms, streetlights, electric gates, and electric toys. ▪ To know importance of insulation.		functionality of the robot and appliances is not indicated.

Table 4.12 illustrates the overall rating of category 2 questions 2.1-2.4. The curriculum saliency category indicates that the participants have limited knowledge of this category. They have a challenge in identifying the big ideas, ranking the big ideas and relating the big ideas to subordinate ideas.

Table 4.12 Category 2 Curriculum Saliency Ratings of Questions 2.1-2.4

No.	P01	P02	P03	P04	Overall Rating Limited
2.1	Limited	Limited	Limited	Limited	Limited
2.2	Limited	Limited	Limited	Limited	Limited
2.3	Limited	Limited	Limited	Limited	Limited
2.4	Limited	Developing	Limited	Limited	Limited

4.4.2.1.3 Category 3: Difficult ideas to teach electric circuits.

3.1 Identify the three electric circuits concepts that are difficult to teach the learners efficiently according to your experience and what do you think the reasons for this are.

This category is establishing the knowledge of the teachers about the ideas that are difficult for the learners. Question 3.1 required the participants to portray their knowledge or understanding of concepts that are difficult for the learners. Some participants were able to provide the concepts that are difficult to teach and reasons.

The responses, analysis, findings, and ratings of this category are illustrated in the table 4.13 below.

Table 4.13 Category 3 Difficult Ideas to Teach Electric Circuits Analysis, Findings and Ratings for Question 3.1

Participant	P01	P02	P03	P04
Rating	**Basic**	**Developing**	**Developing**	**Limited**

Responses

P01:

2	Bulb	The connections of the wires together with the cell in an electric circuit board.
	Circuit with a motor as an output device.	The direction in which motors turn changes if the connectors are swapped around.
3	Series and parallel circuits. (circuit with a buzzer)	I think, Components with polarity must be inserted the right way around the circuit otherwise the circuit will not work

P02:

3.1 Identify the three electric circuit concepts that are difficult to teach the learners efficiently according to your experience and what do you think the reasons for this are.

Concept	What do you think the reasons are for this
1 The electric circuit is the path for transmitting electric current.	Learners have a difficult time understanding the new concept and the difinitions of the new concept that they are learning. They also do not understand the different types of complex circuits.
2 The electric circuit materials provide the charged particle if electric current is available.	There are many things to learn in this concept. You have to properly understand electric circuits and then learn about charged particles which has many concepts that you have to learn. The learners have difficulty understanding electric circuit alone then have to add charged particles on top of that.
3 If the current is available in a circuit the energy flows from the battery to the external circuit.	Too many different concept to understand

P03:

Concept	What do you think the reasons are for this
1 The electric circuit materials provide the charged particles if the electric current is available.	Language is the barrier to our learners, in rural schools. The shortage of equipment for practical purpose, it make life to be difficult, to make learners understand the concept.

P04:

3.1 Identify the three electric circuit concepts that are difficult to teach the learners efficiently according to your experience and what do you think the reasons for this are.

Write your response in the table below.

Concept	What do you think the reasons are for this
1 series and parallel circuits	i think the reason is that there can be circuits that can be both series and parallel and it becomes difficult for learners to understand this
2 current	the issue of current and the difference in terms of current between parallel and series circuits and series-parallel circuits
3	understanding the factors that affects the current in a circuit

Findings	▪ **Concept 1:** Cells and batteries were identified by the participant as difficult concepts. The reason for the choice was that the learners do not understand it without further explanation. ▪ **Concept 2:** The circuit reason is unclear. ▪ **Concept 3:** Series and parallel circuits are identified as difficult the reason being polarity.	▪ The participant was able to share the concepts that are difficult to learners and the reasons are provided. ▪ **Concept 1:** The electric circuit is the path for transmitting electric current. The reason being that the learners find it difficult to define electric circuits. ▪ **Concept 2:** The concept provided electric circuit ▪ material that provides charged particles if electric current is present. The reason this concept is difficult is that the learners need to understand different concepts to master,	▪ The participant was able to give the concepts that are difficult to the learners, and the reasons are provided. ▪ **Concept 1:** The concept is to provide electric circuit material that provides charged particles if electric current is present, but the reason that is chosen by the participant relates to the shortage of resources, making it clear that language is a barrier. ▪ **Concept 2:** The learners do not know that in a battery, there is a	▪ Two concepts are identified. ▪ The difficult concepts that are identified include: - ○ Series and parallel circuits ○ current ▪ The reasons for choosing series circuits are not clear.

	including the electric circuit as well as charged particles. ▪ **Concept 3:** If current is available in a circuit, the energy flows from the battery to the external circuit. There were too many concepts to be understood but the participant did not indicate those concepts.	chemical, resulting in the generation of energy. ▪ **Concept 3:** An electric circuit is a system. Learners do not understand how the components in a circuit work.

Table 4.14 illustrates summary of the rating of question 3.1

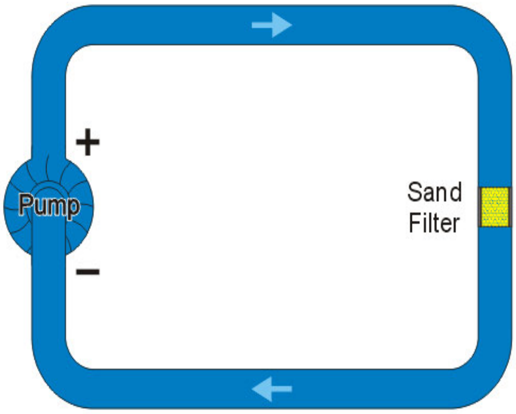
Table 4.14 Summary of Category 3 Difficult Ideas to Teach Ratings of Question 3.1

No.	P01	P02	P03	P04	Overall rating
3.1	Basic	Developing	Developing	Limited	Basic

4.4.2.1.4 Category 4 – Representations

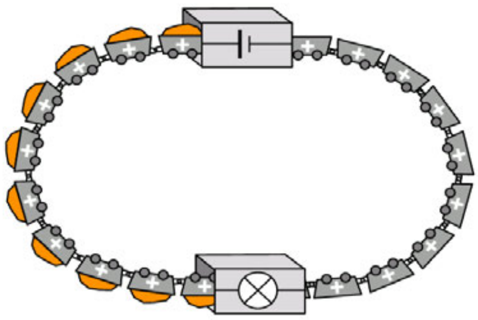
4.1 The representations of teaching the concept of current are given. What do you like or dislike about each representation that is provided below? Provide the reason why one representation is better than another. Write you answer in the table provided.

Representation 1



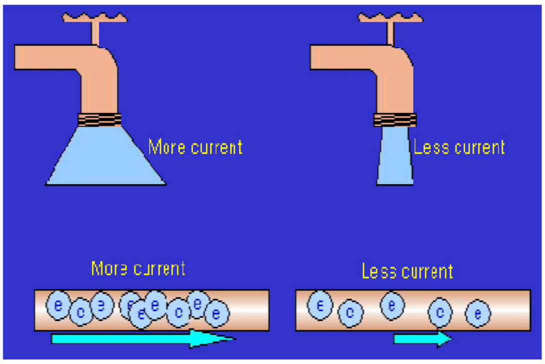
https://www.google.com

Representation 2



https://www.google.com

Representation 3



https://www.google.com

All the four participants indicated what they liked about the representation, but some could not clearly indicate the reasons for disliking the Representations. The overall rating in this question is developing, indicating that the teachers know the representations. Table 4.15 illustrates the responses of the participants, findings, and rating of question 4.1

Table 4.15 Category 4 Representations, Responses Analysis, Findings and Rating for Question 4.1

Participant	P01	P02	P03	P04
Rating	**Developing**	**Developing**	**Developing**	**Basic**

Responses

P01

Representation	What I like about each representation and the reason why I like it.	What I dislike about each representation and the reason why I like it.
Representation 1	I like that the current from pump moves the positive terminal to the negative terminal.	It does not tell us exactly about the sand. What did the do when meet the sand?
Representation 2	~~From the battery,~~ It shows the connection through current from positive terminal passes each other to bulb, and again back to the battery.	It does not tells us anything about negative terminal because it is needed.
Representation 3	It seems as if the tap is opened widely on the more current rather than the less current.	When the more current are laying which are close to many particles it's like the germs when they are pilled together in you to promote that sickness.

P02

Representation	What I like about each representation and the reason why I like it.	What I dislike about each representation and the reason wh[y I] like it.
Representation 1 Water analog[y] circuit	The water/Hose analogy. it is useful for explaining voltage, current and power. charge is water, voltage is the pressure of water, current is the flow of water. Power is the total amount of water flowing in given time.	No electric or magnetic fields. This makes for sil[ly] capacitor analogies and makes explaining impossi[ble] some non-linear compo[nents] could be explained by p[...] ring pressure or flows [...] it get complicated.
Representation 2 Coulomb train model	The model. It provides a physical picture to aid students comprehension of many of the electrical equations needed at higher grades. Allows students to see a comprehensive physical analogue of the circuits.	The coulomb train mod[el] only breaks down shor[t] distances.
Representation 3 Current water analogy	Water analogy this analogy is useful when trying to understand series + Parallel electrical current compared an electrical current reaching a split path for parallel electrical component is like water in a river coming to an island in the river.	It has limitations. When things get into the electronics domain, They can be explained by current analogy.

P03

Representation	What I like about each representation and the reason why I like it.	What I dislike about each representation and the reason why I like it.
Representation 1	-This representation clearly shows the direction for the movement of water which in case of electric circuit is current. -It also shows that current is circulating in a circuit.	-It does not clearly shows what happens after water passes through the sand filter
Representation 2	-This ~~representation~~ used some of electric component symbols.	-There is no clear outlining for the direction of trailers.
Representation 3	-It clearly shows the movement of current through the conducting wire in the form of electrons or electric charges.	-There is no clarification [illegible] conductor size and how it affect the movement of charges.

P04

Representation 1	i like the fact that it's a very simple drawing.	its simple but cannot be effectively utilized in teaching as it doesn't display necessary details like the flow of current
Representation 2	it can be useful in the classroom	representation 2 seems to only have positive and no negative on the diagram
Representation 3	the third diagram seems to be the best in terms of showing the amount of current in a circuit	it doesn't show it in way that looks more like a circuit

Findings	**Representation 1:** What the participant likes is indicated as it shows the current flowing from the positive to the negative terminal. What the participant dislikes is that there is no clear indication of what happens when water reaches the sand. **Representation 2:** What the participant likes is that this representation embodies the current flowing from the positive terminal to the bulb and back to the battery. What the participant dislikes is that the representation does not show a negative terminal, which is a misconception.	**Representation 1:** What the participant likes is indicated as this analogy could be used to resemble the current to the flow of water. What the participant dislikes likes is not clear. **Representation 2:** What the participant likes is that this representation provides a concrete analogy of the circuit. What the participant dislikes is not clear. **Representation 3:** What the participant likes about this analogy is that it is used to understand the electric current. What the participant dislikes is not clear.	**Representation 1:** What the respondents liked is that the representation signifies the circuit, and the direction of water represents the direction of the current in a circuit. What the participant dislikes about this is that it does not show what happens after the water passes the sand filter without relating it to the electric circuits. **Representation 2:** What the respondent likes is that the representation shows the electric components, but the names of the components are not indicated.	**Representation 1:** What the respondent liked was a simple drawing. This was not linked to the way the electric circuit works. What the participant disliked is that it does not show the flow of current. **Representation 2:** What the respondent liked is being useful in the classroom without indicating how it relates to electric circuits. A clear reason is provided with regards to what and the why the participant dislike the other end of the train which is a misconception to say the current becomes less after passing the lamp. **Representation 3:** What the participant likes is indicated and is related to the current in a circuit.

Representation 3: What the participant likes is the depiction of more current by the analogy of the tap being opened fully. What the participant does not like is not clear.	The explanation of what the whole representation depicts is not indicated. What the respondent dislikes is that the direction of the trailers is not indicated. **Representation 3:** What the participant likes about this representation is that it indicates the movement of the current. What the participant dislikes about this representation is that it does not show the conductor size and its impact on the movement of charge. There was no explanation relating to the taps and water.	What the participant dislikes is that this representation does not look like a circuit.

4.2 Identify the representation that you like the most among the ones that are indicated in 4.1 and how would you use these representations in a lesson.

All the four participants indicated what they liked about the representation, but some could not clearly indicate the reason for disliking the Representations. Table 4.16 illustrates the participants' responses, findings, and ratings for question 4.2

Table 4.16 Category 4 Representations Analysis, Findings and Ratings for Question 4.2

Rating	**Developing**	**Developing**	**Developing**	**Basic**
Participant	**P01**	**02**	**P03**	**P04**
Responses	Representation I like the most. | How would you use the representation selected in a lesson. Representation 2 | It is more clearly because you have seen the cell, the bulb and the current flow. It is going to show you exactly when the flow of current is more, the bulb will be lighting, after few minutes will bust. If it less current, it will shown by not brighten the bulb.	Representation I like the most. | How would you use the representation selected in a lesson. It is an excellent 'Bridging analogy' that helps students visualise the invisible. It is a stepping stone that provides some concrete representations of abstract quantities	Representation I like the most. | How would you use the representation selected in a lesson. Representation 2 | . Teach learners how does current is being consumed by external components in a circuit. Components like light bulbs. Which causes resistance in flowing of electric charges.	**Representation I like the most.** it displays the current available in the circuit much better so it'll be easy explaining the flow of current with it, the taps being the sources (battery)
Findings	**Representation 2:** is chosen as the one that the participant likes the most because it is clearly depicting the cell, bulb,	▪ The representation that the participant likes the most is **representation 1** and the reason being that it makes the students see what is abstract,	▪ The representation that the participant likes the most is identified as **representation 2.**	▪ The representation that is liked by the participant is **representation 2.** ▪ The reason provided is that it explains the flow of current.

and the movement of the current.	but there is no explanation related to how it could be done in a lesson.	▪ The participant indicates that this representation could be used to show the learners how the current is consumed, which is incorrect.

The overall rating of representations category is developing as illustrated in Table 4.17

Table 4. 17 Overall Rating of Question 4.1-4.2

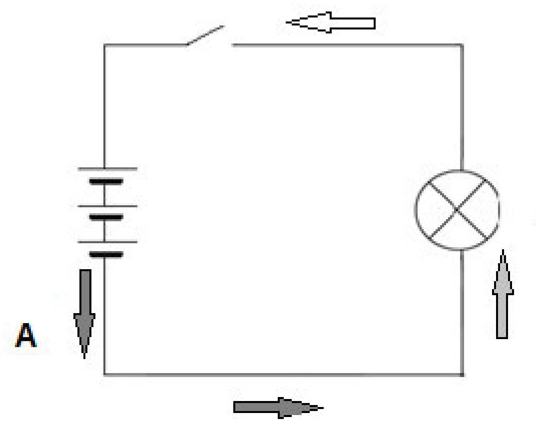
No.	**P01**	**P02**	**P03**	**P 04**	Overall rating Developing
4.1	Developing	Developing	Developing	Basic	Developing
4.2	Developing	Developing	Developing	Basic	Developing

4.4.2.1.5 Category 5: Conceptual teaching strategies of electric circuits

5.1 Examine the responses of the learners to a classroom activity below and explain the strategy that you would use to help the learners. Some of these responses are correct, and some are incorrect.

Activity

The following diagram shows the arrow leaving the battery full of energy at A if the circuit is closed. Answer the questions that follow.



(i) **What is represented by the arrow?**

Electricity

Correct answer: electron.

The movement of electrons is electricity (Marks, 2012).

Electricity refers to the movement of electrical power or charge.

(ii) **What is represented by the shaded part of the arrow?**

Current

Correct answer: Energy

Chitta (2019) regards the current as the charges that are in motion.

Electric current is the movement of negative charges(electrons) from the negative terminal of the source of power to its positive terminal **(Wang, 2019).**

Electrical devices use up energy (Edminister & Mahmood, 2018).

The electrons are not used up therefore the charge stays the same (Kang, 2018).

(iii) **Where does the arrow get energy from?**

Battery

Correct answer: from the chemical reaction in the cell/battery

The battery converts chemical energy to electrical energy, and the charge is not stored by the battery, but it stores chemical potential energy (Buchla & Floyd, 2020). Kang (2018) denotes that the chemical energy is converted to electrical energy.

(iv) What happens when the arrow moves from the positive terminal to the negative terminal of the cell?

The charge in the arrow is consumed.

Correct answer: the energy in the circuit to the components is consumed.

The electrons and protons are not used up, therefore the quantity of charge does not change (Kang, 2018).

(v) Is it correct to say that the electric current is consumed? Explain your answer.

Yes, the current is consumed because as it moves around the circuit, it gets used up as it produces heat and light, and by the time it gets back to the battery, all the current is finished. Correct answer: no, the electrical energy is changed to another form, for instance, light or heat, causing energy represented by the arrows to diminish.

5.1 What are the concepts that are known by this learner in the activity? Write your answer in the space provided.

The participants indicated what this learner knows. The concepts that the learners know include charge, negative and positive terminals, the battery, electricity and current. The explanations were not indicated. The misconceptions were not indicated. Table 4.18 illustrates category 5 responses, findings, and ratings of question 5.1.

Table 4. 18 Category 5 Conceptual Teaching Strategies of Electric Circuits Analysis, Findings and Ratings for Question 5.1

Participant	P01	P02	P03	P04
Rating	**Developing**	**Limited**	**Limited**	**Basic**
Responses	**5.1 What are the concepts that are known by this learner in the activity. Write your answer in the space provided.** The learner know the electricity and how it has been transported to the whole circuit. What does the battery do in the whole circuit when it is ~~not~~ closed.	5.1 What are the concepts that are known by this learner in the activity. Write your answer in the space provided. 5.1- closed + open circuits -The current flows through each component in series circuit -The flow of charge is called electric current. -In parallel circult the current is divided. -How a circuit works.	5.1 What are the concepts that are known by this learner in the activity. Write your answer in the space provided. -This learners know that when current is available in a circuit, the energy flows from battery to the external parts OR components of the circuit. -They also know that the net flow of charges in a circuit is known as electric current. -The electric current energy that is supplied by the battery is used by components in the circuit -The learners are able to understand what happened to the shaded arrows after passing through the bulb	5.1 What are the concepts that are known by this learner in the activity. Write your answer in the space provided. The learner understands that the current is the flow of charges, and understands the negative and positive terminals. The learner also understands what a battery is and what it does in a circuit

Findings	▪ The participant identified what the learner knows- ○ electricity ○ battery but did not specify what the battery does. ▪ The misconceptions were not identified.	▪ The concepts that are provided are not linked to the answers provided by the learners. ▪ Misconceptions are not indicated.	▪ The participant did not link directly concepts as depicted in the learner activity. ▪ The participant indicates that the learner knows that: ○ The current is made available by the battery. ○ Misconceptions are not indicated.	▪ The participants indicate the concepts that are known by the learner, e.g., charge, negative and positive terminals, and battery. ▪ The explanation is not indicated. ▪ Misconceptions are not indicated.

5.2 What are the gaps with regards to concepts that are displayed by this learner in the activity? Write your response in the space provided.

The gaps related to the concepts were noted in the questions where the learner provided the wrong answers. Table 4.19 exemplifies category 5, responses, findings, and ratings of question 5.2

Table 4.19 Category 5 Conceptual Teaching Strategies of Electric Circuits Analysis, Findings and Rating for Question 5.2

Participant	**P01**	**P02**	**P03**	**P4**
Rating	**Limited**	**Limited**	**Limited**	**Basic**
Responses		5.2 What are the gaps with regards to concepts that are displayed by this learner in the activity. Write your response in the space provided. The circuit is opened not closed, that is why the current does not flow accordingly because there is a shortage of current It tells us that the battery that the learner used have different voltages 5.2. The learner does not use the specific terms when explaining certain component	5.2 What are the gaps with regards to concepts that are displayed by this learner in the activity. Write your response in the space provided. -The learners know, that if the current is available in a circuit, the energy flows from the battery to external part of circuit, But there is a misconcept in the direction in which energy flows between the positive and negative terminals.	The current is not consumed, energy is consumed. The arrow represents the direction of flow of charges

Findings	The gaps with regards to the concepts were not identified.	▪ There is no explanation related to electricity, battery, energy and current.	▪ The gaps or misconceptions evident in the learner activity are not indicated.	▪ The participant indicated the misconceptions: - o The current is not consumed; it is the energy that is consumed. o The participant did not indicate that the learner still confuses the electricity and charge.

5.3 What are teaching strategies you would use to bridge the gaps identified in 5.2. Write your answer in the space provided.

This category seeks to establish the teachers' knowledge of teaching strategies for electric circuits. The teachers could identify the teaching strategies, but some did not provide the clear explanation in terms implementing the strategies. Table 4.20 illustrates category 5 participants' responses, findings, and rating for question 5.3.

Table 4.20 Category 5 Conceptual Teaching Strategies Analysis, Findings and Rating for Question 5.3

Participant	**P01**	**P02**	**P03**	**P04**
Rating	**Limited**	**Basic**	**Basic**	**Basic**
Responses	5.3 What are teaching strategies you would use to bridge the gaps identified in 5.2. Write your answer in the space provided. I think you must use correct materials especially the correct size of the cell. The connections of the cell or wires loose and a short circuit happens.	5.3 What are teaching strategies you would use to bridge the gaps identified in 5.2. Write your answer in the space provided. -Regulary revise the basics of circuits so that the learners understand the different concepts better.	5.3 What are teaching strategies you would use to bridge the gaps identified in 5.2. Write your answer in the space provided. -By using the provided circuit, I can go through each component with learners, Ask them questions and make them explain or justified justify their responses to ensure they really understand each component in detailed. In this case here,I would start from the battery to explain how does it work to produce energy that leaves the battery in the form of electric current. -Tell them that current battery via positive terminal in the form of electric charges.	I play ice breaking games with learners that test their knowledge i use interactive quizzes to spark memory of their past learning as to ensure that new kn easily absorbed and understood by the learners One of the strategies that I use when teaching electrical circuits is BOD MODELLING. i for instance make an abstract concept of moving elec more visible to the learners by having them use their bodies to create n
Findings	▪ The gaps were not related to the concepts depicted.	▪ Revision of circuits but the concepts are not indicated.	P03 is using the following strategies when teaching electric circuits: ▪ Teacher-directed strategy: go through circuits with learners.	The strategies were indicated without elaborating on how these could be used in electric circuits: ▪ Ice breaking games. ▪ Quizzes. ▪ Body modelling.

- Ask questions to make the learners explain and justify responses about circuit components.
- Telling them about the charge.
- Use representation when going through circuit components.
- Nothing is said about teaching electric energy.
- No misconceptions are identified.

Table 4.21 illustrates the Category 5 Summary of Overall Rating

Table 4.21 Category 5 summary of overall rating

No.	P01	P02	P03	P 04	Overall rating Basic
5.1	Developing	Limited	Limited	Basic	Basic
5.2	Limited	Limited	Limited	Basic	Limited
5.3	Limited	Basic	Basic	Basic	Basic

4.4.2.1.6 Category 6 - Teaching resources for electric circuits

This category seeks to establish the teachers' knowledge of teaching resources for electric circuits.

6.1 How do you address the issue of resources when teaching electric circuits? Explain in detail. Write the answer in the space provided.

The resources that are pointed out by the participants when teaching electric circuits include the textbooks, Sasol Inzalo workbooks, pictures of electric circuits, charts of electric circuits, analogies, and electric circuit models. Most teachers point out how they use the resources. The overall rating in category 6 is developing. This indicates that the teachers have knowledge of resources when teaching electric circuits. Table 4.22 illustrates the responses, findings, and rating of question 6.1

Table 4.22 Category 6 Teaching Resources for Electric Circuits Responses, Findings and Rating of Question 6.1

Participant	P01	P02	P03	P04
Rating	**Developing**	**Basic**	**Basic**	**Basic**
Responses	6.1 How do you address the issue of the resources when teaching electric circuits? Explain in details. Write the answer in the space provided. Before you can do the practicals of the electric circuits, you need to have correct different resources so that can accomodate half of the class so that they will work in pairs. Check the resources before the practical day especially cell and bulb. The practical resources are not available, I rely on different textbooks and a Sasol workbooks so that they can see the pictures of electric circuit. I also use charts with electric circuits.	6.1 How do you address the issue of the resources when teaching electric circuits? Explain in details. Write the answer in the space provided. When teaching electric circuits, You need the following resources. Small light bulb, 2 batteries, 2 Alligator clip wires or aluminum foil, paper clips, electrical tape, bulb holders and battery holders. Since we do not have these resources I use examples of circuits that they would know such as fridges, refridgerator freezers and televisions We also get diffent types of diagrams such as the water analogy and colomb train model Usually analogy use the coulomb train model so the learners can have a better understanding of circuits because trains are common to see.	6.1 How do you address the issue of the resources when teaching electric circuits? Explain in details. Write the answer in the space provided. -Teaching resources for electric circuits in my School remain a challenging issue because there is nothing at all. I have asked teaching resources and they keep promising. -Teaching electric circuits at my school limits me on my lessons because I teach lessons that are teacher based. I cant let learners have their own experimental equipment in the class during a lesson. I am the only one who has to connect circuit to show them, Due to the shortage of teaching kits.	6.1 How do you address the issue of the resources when teaching electric circuits? Explain in details. Write the answer in the space provided. One of the strategies that I use when teaching electrical circuits without circuit boards is BODY MODELLING. i for instance make an abstract concept of moving electrons more visible to the learners by having them use their bodies to create models

Findings	▪ The resources to do practical activities are not available. ▪ The learners share in pairs the limited resources. ▪ Textbooks and Sasol Inzalo workbooks are used to teach practicals to observe the pictures of electric circuits. ▪ Charts with electric circuits are also used.	▪ The participant indicates the shortage of resources. ▪ The participant uses analogies.	▪ The participant highlights the shortage of resources. o There is a shortage of resources in a school. o The resources are not enough, hence the teacher demonstrates the circuits.	▪ The participant uses representation/analogy (body modelling) to demonstrate the concept of electrons.

The rating of category 6 is developing. Table 4.23 illustrates a summary of the rating of 6.1

Table 4.23 Category 6 Overall Rating of 6.1

Participants	**P01**	**P02**	**P03**	**04**	**Rating**
6.1	Developing	Basic	Basic	Basic	Basic

4.4.2.1.7 Category 7 - Technologies for teaching electric circuits

According to white paper on e-learning (Education, 2004), Information and Communication Technologies (ICT) should be implemented to enhance learning and teaching.

7.1.1 How do you use ICT when teaching electric circuits? Explain in detail. Write your answer in the space provided.

The teachers have some knowledge of technologies that are used in teaching electric circuits. One participant did not indicate technologies for teaching electric circuits. They portrayed their knowledge of the ICT resources, including a smartboard, laptop, router, YouTube video, Science websites and accessing workbooks and worksheets via WhatsApp quizzes. Table 4.23 Illustrates category 7 analysis, responses, findings, and ratings of question 7.1 The overall rating in category 7 is Basic and it is illustrated in table 4.25. Most teachers are using technologies for teaching Technology.

Table 4.24 Category 7 Technologies for Teaching Electric Circuits, Analysis, Findings and Rating for Question 7.1

Participant	P01	P02	P03	P04
Rating	Basic	Limited	Basic	Basic
Responses	7.1 How do you use ICT when teaching electric circuits? Explain in details. Write your answer in the space provided No I did not use it because of lack of OHP and also with other facilities. Data and blue load shading thing because the theme take that particular thing (OHP) over head projector. I recieve the workbook with worksheets via whatsup and print the workbook and worksheet using computer about electric circuits	7.1 How do you use ICT when teaching electric circuits? Explain in details. Write your answer in the space provided Universities and Industries collaborated to bulb modular educational programs that allow learners to improve their education and knowledge. The goal is to develop and bring multimedia enhanced courseware into the classroom. They also want to interactively 'narrowcast' state-of-the-art lectures into school and ultimately onto their desktop two approaches are being evaluated at many schools across the country. The new methods are known as computer Based Instruction (CBI) and Interactive Distance Learning (IDL) to demostrate the basic concepts of electricity. The module starts with a simple electric circuit that consist of a Voltage source, a variable resistor, a light bulb and a switch as the student clicks on the switch to close it, the electric current flows in the circuit which in turns the light on. This animation shows the relationship between closing the switch current flow and light.	7.1 How do you use ICT when teaching electric circuits? Explain in details. Write your answer in the space provided ICT. is impossible to my school, There are no technology teaching gadgets such as computers, tablets or school monitored laptops. But what I do is to download videos on my computer and play it to them. (learners)	7.1 How do you use ICT when teaching electric circuits? Explain in detail. Write your answer in the space provided My school does not have computers or tablets but we however do have smart boards, projector and phase laptops. When teaching electrical circuits I connect to my personal router. I first prepare for a lesson, connect and research on other strategies that are utilized by other educators in teaching circuits. I then integrate these strategies with my strategies that I will use during my teaching. I create slides of simplified information that will easily be grasped by the learners. I the use videos and illustrations on youtube or science websites that I've selected earlier as relevant ones to play for my learners, we then go through quizzes displayed on the board together with my class.

Findings	P01 does not use ICT because of the unavailability of the overhead projector, other facilities, loadshedding and data. The workbooks with worksheets are accessed via WhatsApp. Workbooks and worksheets with electric circuits are printed using the computer.	No indication of how the participant uses ICT.	The school's ICT resources are not available. The participant uses their own laptop. There is no indication with regards to how the aspects of the circuits are presented using a video.	ICT resources that are available include smartboards, projectors, phase laptops and personal routers. Slides are created and used. YouTube videos are used. Relevant Science websites and Quizzes. There is no indication of how the aspects of circuits are used.

Summary of category 7 rating is illustrated in Table 4.25.

Table 4.25 Summary of Category 7 Rating

Participant	**P01**	**P02**	**P03**	**P04**	**Overall rating**
					Basic
7.1	Basic	Limited	Basic	Basic	Basic

.4.2.1.8 Category 8: Learner diversity for inclusive teaching of electric circuits

According to the guidelines for inclusive teaching and learning (Education, 2010), one of the barriers identified is the language and communication barrier since the language of teaching and learning is not the home language for some learners. The performance of the learners is also associated with the language of teaching and learning, and the Department of Basic Education introduced English across the curriculum strategy (EAC) to bridge the barrier of language of teaching and learning that is implemented in all content subjects, including Technology**.**

What are the 3 language skills that are supposed to be evident in the Technology lesson to address the issue of EAC when teaching electric circuits? Write the answer in the space provided. The participants were able to identify the correct EAC skills, including listening and speaking, reading, and viewing and writing and presenting. The teachers' knowledge of EAC skills is Exemplary indicating that they know these skills. Table 4.26 Illustrates the responses, analysis, findings, and ratings of question 8.1

Table 4.26 Category 8 Learner Diversity for Inclusive Teaching of Electric Circuits Responses, Findings and Ratings for Question 8.1

Participant	P01	P02	P03	P04
Rating	**Exemplary**	**Exemplary**	**Exemplary**	**Limited**
Responses	1. Reading & Viewing (Reading and viewi- 2. Listening and speaking 3. Writing and presenting	- Reading and viewing. - Writting and presenting - Listening and speaking	8.1 What are the 3 language skills that are supposed to be evident in Technology lesson to address the issue of EAC when teaching electric circuits. Write the answer in the space provided. 1) In my experience of teaching both technology and Mathematics learners are not able to write English sentences that make sense when you are reading it. regardless of the correctness of spelling. 2) Learners are unable to read and understand questions that are written in teaching and learning language. This is very challenging part in teaching profession especially in deep rural schools. Where English is not a home language 3) Listening and speaking English.	learners must be able read and understand english language used in circuits learners must be able write the language of learning and instruction learners must be able to interpret instructions
Findings	The correct EAC skills were provided: - Reading and viewing, Listening and speaking. Writing and presenting.	The participant indicated the EAC skills: - o Reading and viewing. o Writing and presenting o Listening and speaking	The participant identifies the following skills: - ▪ Reading. ▪ Writing. ▪ Listening and speaking.	▪ The skills that were identified include reading and writing.

8.1 How do you implement EAC when teaching electric circuits? Explain in detail. Write your answer in the space provided.

The teachers portrayed the knowledge of implementing EAC to a certain degree. The overall teachers' knowledge of implementing EAC is exemplary. Table 4.27 illustrates the participants' responses, analysis of findings and rating of question 8.2.

Table 4. 27 Learner Diversity for Inclusive Teaching of Electric Circuits Analysis, Findings and Rating for Question 8.2

Participant	P01	P02	P03	P04
Rating	**Exemplary**	**Developing**	**Basic**	**Limited**
Responses	8.2 How do you implement EAC when teaching electric circuits? I Write your answer in the space provided. I use the resources /i to explain the meaning together with the pic if I cannot find the component. -They read and under meaning and the func the components of elec -The learners write thei about connecting electric they will present it tog their ~~findings~~ drawings. -The learners listen to the the words bulb, conductor parallel etc. I give them to match the object a together with their func	-Reading and Viewing By viewing a VD reading you are ens understands the lesson. Viewing elec absolutely crucial for documenting a info writing and presenting. Using differenting types of symbols t and using diagrams to present to the and speaking. Listening to the learners questions a Speaking to the learners in a way that t understand.	8.2 How do you implement EAC when teaching electric circuits? E Write your answer in the space provided. -Conducting my lessons with Eng learners to only respond or ask with leaning and learning langua -Controlling the proper usage of of correct spelling and words give a clear clarification betwee are almost read the same suc resistance.	before i begin to explain the electric circuits and what they are, i explaining meaning of concepts that will be key in understanding may not be able to understand. i then ask that they write definitio make sure that even when i am not around and they have work t understand and be able to respond to questions.
Findings	▪ The participant uses charts to explain the meaning with pictures if the real object is not available. ▪ Learners read the meaning and functions of components of electric circuits. ▪ Learners present their findings and	The EAC is implemented when: - ○ Viewing electric drawing. ○ Presenting circuits using diagrams.	▪ The implementation that is evident is reading, writing, and speaking.	The implementation of EAC taking cognisance of writing and presenting, reading, and viewing, listening, and speaking is

drawings of electric circuits. ▪ Learners listen to the meaning of the word's bulb, conductor, series and parallel. ▪ Worksheet to match symbols of the object that are viewed. ▪ The representations are indicated such as drawings, charts, bulbs, conductors, series and parallel.		not explained adequately.

Table 4.28 Illustrated the summary of category 8 rating.

Table 4.28 Summary of Category 8 Rating

No.	P01	P02	P03	P04	Overall rating Developing
8.1	Exemplary	Exemplary	Exemplary	Limited	Exemplary
8.2	Exemplary	Developing	Basic	Limited	Developing

4.4.2.1.9 Category 9: Assessing electric circuits

9.1.1 Explain in detail the methods you use to assess the learners' understanding of electric circuits.

This question determines the knowledge of the participants on the assessment of electric circuits thus indicating the knowledge of teachers relating to assessing electric circuits. Table 4.29 illustrates the responses, findings, and rating for question 9.1

Table 4.29 Category 9 Assessing Electric Circuits Responses, Analysis, Findings and Ratings for Question 9.1

Participant	P01	P02	P03	P04
Rating	Basic	Basic	Developing	Developing
Responses	9.1 Explain in details the methods you use to assess the learners' understandir g of electric circuits. Practical :- I start with a group, where they will make a circuit. They will demons what did they do. Individual drawing :- - They will draw what they do in that circuit, afte they will make it individua in different places. They will scattered together with their circuit board and compo	9.1 Explain in details the methods you use to assess the learners' understanding of electric circuits. - Having weekly sport test so i can assess their strengths and weakness in different concepts. - Asking questions as i teach the lessons. - Ask students to reflect and write down that they have learned. - Using quizers, giving short quizzers at the end of the class to check understanding. - Pair then with partners to compare thoughts. - 3-2-1 method ask 3 things they have learnt from your lesson, 2 things they want to know more about and 1 Question they have. - Misconception check ask them whether they agree or disagree and to explain why.	9.1 Explain in details the methods you use to assess the learners' understanding of electric circuits. - If the lesson was practical and it was about connecting components in series. Learners are being assessed by granted a chance to reconnect the circuit. Similar to parallel circuit. - Learners are shown the pictures of electric components and asked to draw their symbols. Sometime short test like quiz are conducted.	First before we begin the electric circuits, we do a quick quiz together as a class and i in some cases prepare a baseline and diagnostic assessment to know how to go about presenting my lesson. electric circuits also have drawings that learners must be able to do i.e circuit diagrams, i give learners an opportunity to show their understanding by drawing circuit diagram specified by me. I also at the end of the lesson write circuit concepts and ask that learners define them for me. I also use questions that ask learners to differentiate between concepts to see if they know the differences. i.e parallel and series circuits

Findings	▪ The participant indicated how the assessment will unfold. ▪ Group making a circuit. ▪ Group demonstration of what they made. ▪ Individual assessment through drawing ▪ Individual assessment through making the circuits. ▪ Methods are not named.	▪ The participant uses the following methods: - o Weekly tests o Quizzes ▪ The participant does not indicate the actual concepts assessed.	▪ The participant indicates that the learners reconnect the series and parallel circuits. ▪ The pictures of electric components are used to assess electrical symbols. ▪ Short test as a quiz is used to assess electric components.	▪ The participant gives the learners the quiz. ▪ Before starting to teach the learners, use quiz baseline and diagnostic assessment to inform how to present a lesson. ▪ Ask learners to define concepts and provide differences between concepts.

Table 4.30 illustrates the rating of question 9.1 The overall rating for this category is developing. The teachers portrayed knowledge of formative and summative assessments, meaning weekly tests, quizzes, practicals, use of pictures to assess, short tests, baseline and diagnostic assessments and asking questions.

Table 4.30 Summary of Ratings for Category 9 Assessing Electric Circuits

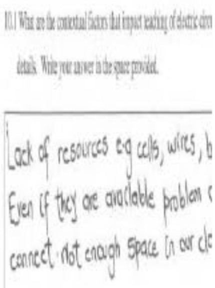
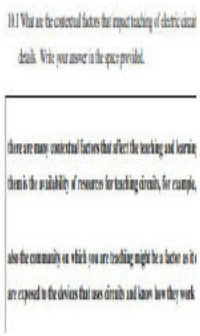
Participants	P01	P02	P03	P04	Overall Rating Developing
Rating	Basic	Basic	Developing	Developing	Developing

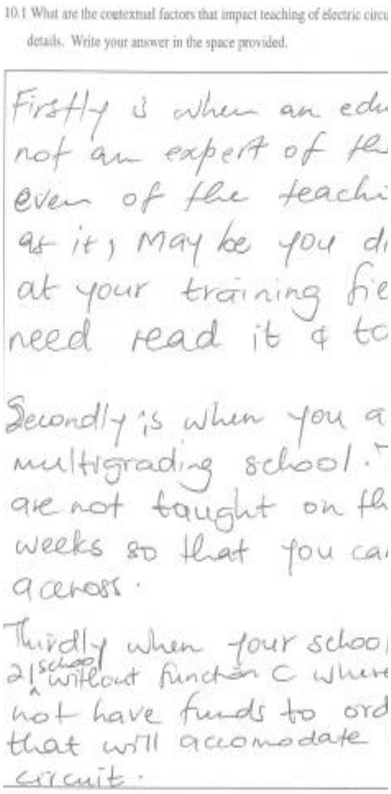
4.4.2.1.10 Category: 10 Various context in which teaching electric circuits takes place.

10.1.1 What are the contextual factors that impact the teaching of electric circuits? Explain in detail. Write your answer in the space provided.

This question is establishing the participants' knowledge of the various contexts in which the teaching of electric circuits takes place. Table 4.31 illustrates the analysis, findings, and ratings of the teachers' knowledge of various contexts in which the teachers teach electric circuits. The overall rating of this category is basic, which indicates that the teachers know to a certain extent the context in which teaching of electric circuits takes place

Table 4.31 Category 10 Various Contexts in Which Teaching Electric Circuits Takes Place Responses, Analysis, Findings and Rating for Question 10.1

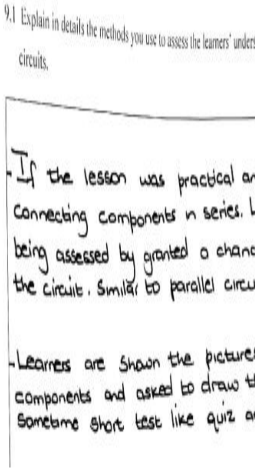
Participant	P01	P02	P03	P04
Rating	Basic	Developing	Limited	Limited
Responses		 10.1 What are the contextual factors that impact teaching of electric circ details. Write your answer in the space provided. Lack of resources e.g cells, wires, b Even if they are available problem c connect. not enough Space in our cl		 10.1 What are the contextual factors that impact teaching of electric circuit details. Write your answer in the space provided. there are many contextual factors that affect the teaching and learning them is the availability of resources for teaching circuits, for example, also the community on which you are teaching might be a factor as it are exposed to the devices that uses circuits and know how they work


10.1 What are the contextual factors that impact teaching of electric circu
details. Write your answer in the space provided.

Firstly is when an edu
not an expert of the
even of the teachi
as it, may be you di
at your training fie
need read it & to

Secondly is when you a
multigrading school. T
are not taught on the
weeks so that you can
across.

Thirdly when your schoo
is school without function C where
not have funds to ord
that will accomodate
circuit.


9.1 Explain in details the methods you use to assess the learners' under
circuits.

- If the lesson was practical ar
connecting components in series. L
being assessed by granted a chanc
the circuit. Similar to parallel circu

- Learners are shown the picture
components and asked to draw th
Sometime short test like quiz a

Findings	▪ Multigrading. ▪ Funding for resources is not available.	▪ The contextual factors that are indicated by the participant include: ○ Unavailability of the resources, for instance, bulbs and switches. ▪ Shortage of space in	▪ Contextual factors are not identified.	▪ Availability of resources. ▪ Community as a factor in determining the exposure of the learners to devices that use circuits and how

	the classroom to assemble circuits.	they work.

Table 4.32 Illustrates the summary of category 10.1 Rating.

Table 4.32 Summary of Category 10.1 Rating

Participants	P01	P02	P03	P04	Overall rating
10.1	Basic	Developing	Limited	Limited	Basic

Table 4.33 illustrates the qualitative summary of teachers' knowledge of TSPCK findings. The teachers' knowledge of TSPCK is basic.

Table 4.33 Summary of Teachers' TSPCK Categories Qualitative Analysis.

TSPK categories	P01	P02	P03	P04
Category: 1 Learner prior knowledge and misconceptions	Limited	Limited	Limited	Limited
1.1	Limited	Limited	Limited	Limited
1.2	Limited	Limited	Limited	Limited
Category: 2 Curriculum saliency	Limited	Limited	Limited	Limited
2.1	Limited	Limited	limited	Limited
2.2	Limited	Limited	Limited	Limited
2.3	Limited	Limited	Limited	Limited
2.4	Limited	Developing	Limited	Limited
Category: 3 Difficult ideas to teach electric circuits	Basic	Developing	Developing	Limited
3.1	Basic	Developing	Developing	Limited
Category: 4 Representations	Developing	Developing	Developing	Basic
4.1	Developing	Developing	Developing	Basic
4.2	Developing	Developing	Developing	Basic
Category: 5 Conceptual teaching strategies of electric circuits	Basic	Limited	Limited	Basic
51	Developing	Limited	Limited	Basic
5.2	Limited	Limited	Limited	Basic
5.3	Limited	Basic	Basic	Basic

Category: 6 Teaching resources for electric circuits	Developing	Basic	Basic	Basic
6.1	Developing	Basic	Basic	Basic
Category: 7 Technologies for teaching electric circuits	Basic	Limited	Basic	Basic
7.1	Basic	Limited	Basic	Basic
Category 8: Learner diversity for inclusive teaching of electric circuits	Exemplary	Exemplary	Developing	Limited
8.1	Exemplary	Exemplary	Exemplary	Limited
8.2	Exemplary	Developing	Basic	Limited
Category: 9 Assessing electric circuits	Basic	Basic	Developing	Developing
9.1	Basic	Basic	Developing	Developing
Category: 10 Various contexts in which teaching electric circuits takes place	Basic	Developing	Limited	Limited
10.1	Basic	Developing	Limited	Limited
Total: 40 (TSPCK categories)				
Competency levels (4)	Basic	Developing	Developing	Basic

Note. Ratings: Limited, Basic, Developing and Exemplary

The Summary TSPCK qualitative rating is basic. Table 4.34 illustrates the overall summary of teachers' TSPCK rating.

Table 4.34 Summary of overall TSPCK Qualitative Analysis and Findings

Participants	Qualitative rating	Scores
P01	Basic	2
P02	Developing	3
P03	Developing	3
P 04	Basic	2
Overall TSPCK rating	Developing	3

4.5. Research question 3: What is the correlation between grade 7 teachers' content knowledge and topic specific pedagogical content knowledge when teaching electric circuits?

The CK and TSPCK were compared to establish the relationship. Qualitative data were converted to quantitative data to allow a comparison of CK to TSPCK. Table 4.33 illustrates the summary conversion of TSPCK qualitative data to quantitative data to establish the relationship that exists. The Pearson moment correlation and the Regression analysis were used to establish the correlation between the TSPCK and CK of the teachers.

Table 4.35 Illustrating the Summary of Qualitative to Quantitative data analysis

TSPK Categories	P01	P02	P03	P04	P01	P02	P03	P04
Category: 1 Learner prior knowledge and misconceptions	Limited	Limited	Limited	Limited	1	1	1	1
1.1	Limited	Limited	Limited	Limited	1	1	1	1
1.2	Limited	Limited	Limited	Limited	1	1	1	1
Category: 2 Curriculum saliency	Limited	Limited	Limited	Limited	1	1	1	1
2.1	Limited	Limited	limited	Limited	1	1	1	1
2.2	Limited	Limited	Limited	Limited	1	1	1	1
2.3	Limited	Limited	Limited	Limited	1	1	1	1
2.4	Limited	Developing	Limited	Limited	1	3	1	1
Category: 3 Difficult ideas to teach electric circuits	Basic	Developing	Developing	Limited	2	3	3	1
3.1	Basic	Developing	Developing	Limited	2	3	3	1

Category: 4 Representations	Developing	Developing	Developing	Basic	3	3	3	2
4.1	Developing	Developing	Developing	Basic	3	3	3	2
4.2	Developing	Developing	Developing	Basic	3	3	3	2
Category: 5 Conceptual teaching strategies of electric circuits	Basic	Limited	Limited	Basic	2	1	1	2
51	Developing	Limited	Limited	Basic	3	1	1	2
5.2	Limited	Limited	Limited	Basic	3	1	1	2
5.3	Limited	Basic	Basic	Basic	1	2	2	2
Category: 6 Teaching resources for electric circuits	Developing	Basic	Basic	Basic	3	2	2	2
6.1	Developing	Basic	Basic	Basic	3	2	2	2
Category: 7 Technologies for	Basic	Limited	Basic	Basic	2	1	2	2

teaching electric circuits								
7.1	Basic	Limited	Basic	Basic	2	1	2	2
Category 8: Learner diversity for inclusive teaching of electric circuits	Exemplary	Exemplary	Developing	Exemplary	4	4	3	1
8.1	Exemplary	Exemplary	Exemplary	Exemplary	4	4	4	1
8.2	Exemplary	Developing	Basic	Limited	4	3	1	1
Category: 9 Assessing electric circuits	Basic	Basic	Developing	Developing	2	2	3	3
9.1	Basic	Basic	Developing	Developing	2	2	3	3
Category: 10 Various contexts in which teaching	Basic	Developing	Limited	Limited	2	3	1	1

electric circuits takes place								
10.1	Basic	Developing	Limited	Limited	2	3	1	1
Competency levels (4)	**Basic**	**Developing**	**Developing**	**Basic**	**2**	**3**	**3**	**2**

Note. Qualitative analysis rating=Limited, Basic, Developing, Exemplary. Limited=1 Basic=2 Developing=3 Exemplary=4

The overall CK and TSPCK data for the individual participants were compared, and Table 4.36 illustrates the quantitative data that were used to establish the correlation between CK and TSPCK when teachers teach electric circuits using Pearson moment correlation. The Pearson Moment correlation is 0,301511. Table 4.36 illustrates the summary of CK and TSPC comparison.

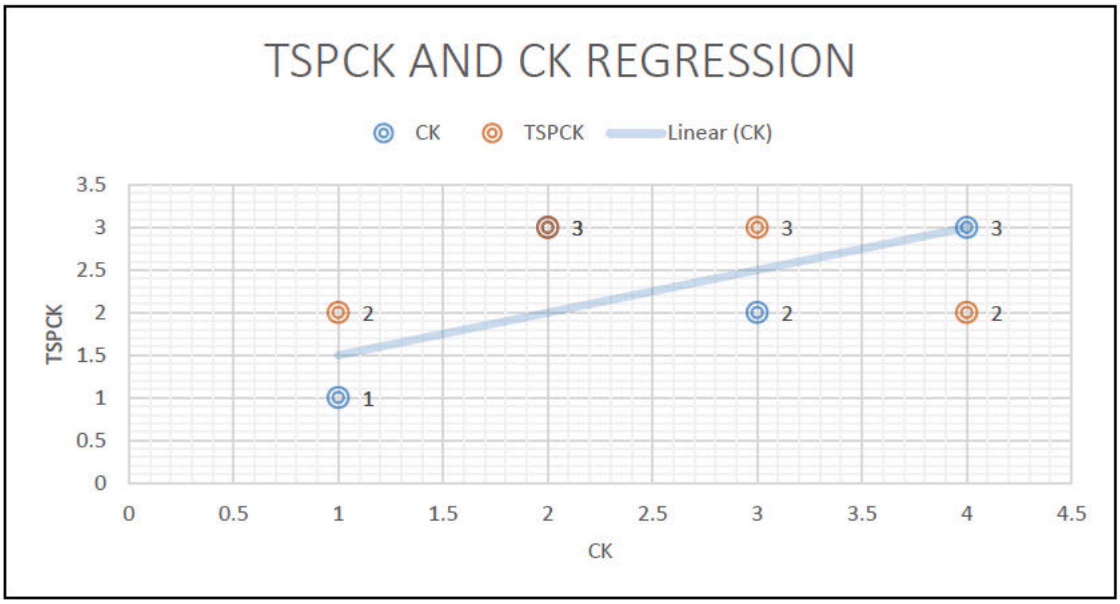
Table 4.36 Comparison of CK and TSPCK

Participants	**TSPCK Quantitative data**	**CK Quantitative data**
P01	**2**	**1**
P02	**3**	**3**
P 03	**3**	**2**
P 04	**2**	**3**
Overall Rating	**3**	**2**

NOTES. Pearson Moment correlation of CK and TSPCK is 0,301511. It is a positive weak relationship in which CK predicts TSPCK. **Translation of Scores: 1 -Limited knowledge, 2-Basic knowledge, 3-Developing, 4-Exemplary.**

Figure 4.5 Illustrates regression to portray the relationship between TSPCK and CK. The findings confirm the weak positive trend. CK predicts TSPCK. However, it is not always the case that CK predicts TSPCK.

Figure 4.5 TSPCK and CK Relationship



4.6 Matters of concern

It was found that the teachers have limited knowledge of curriculum saliency, as well as learner prior knowledge and misconceptions. The teachers might find it difficult to teach electric circuits effectively.

4.7 Conclusion

This chapter dealt with data analysis findings and ratings of CK and TSPCK. Data were analysed qualitatively and quantitatively. The TSPCK knowledge of the teachers is at developing level. The CK of the teachers is at basic level. The correlation of CK and TSPCK is 0,301511, which is a positive weak relationship. The CK predicts TSPCK however the relationship is weak. It is not always the case that CK predicts TSPCK. The gaps related to CK and TSPCK were identified as matter of concern if the teachers teach electric circuits.

CHAPTER FIVE: DISCUSSION OF FINDINGS AND INTERPRETATION

5.1 Introduction

The previous chapter dealt with the analysis of the data, findings and matter of concern considering the research questions. The CK assessment tool questionnaire and the TSPCK assessment tool questionnaire were analysed. The CK assessment tool questionnaire consisted of multiple-choice questions, and the TSPCK assessment tool comprised closed and open-ended questions based on knowledge categories. The discussion of findings in this section is done according to the research questions. Chapter five consists of an introduction, a discussion of findings, recommendations, future research, and a conclusion.

5.2 Research question 1 findings and interpretation: What is the level of grade 7 teachers' content knowledge when teaching electric circuits?

The content knowledge assessment tool questionnaire findings are discussed to answer research question 1. Question 1 determines the participants' knowledge of the conservation of charge, current is not consumed and energy is consumed in a circuit. Kang (2018) points out that the charge remains unchanged or constant and this is named conservation of charge. This means that the charge does not get depleted. The findings in this study revealed that one participant out of the four participants chose the correct option and the level of confidence was confident, which indicates the knowledge of the conservation of charge. However, most participants have limited knowledge which is an indication of the misconception of conservation of charge. The electrons are negatively charged particles that transmit energy from the source of power as electric current that is not used up hence the charge is not used up. On the contrary, in a study that was conducted by (Gaigher & van der Merwe, 2011), most participants had an understanding of the weakening model. The same finding is evident in a study that was conducted by (Gaigher & Moodley, 2017) as all six participants portrayed the knowledge of the attenuation or weakening model.

Question 2 establishes the participants' knowledge of energy being used up in a circuit instead of the current. Two participants chose the correct option; however, one of them was a bit unsure, which meant the answer was considered incorrect. This means that in this question, only one participant got this answer correctly since the participant was also confident with the answer. This portrays that most participants have a limited understanding of energy in a circuit. This is congruent to a study by (Kocakülah & Küçüközer, 2007) when nearly all participants portrayed a misconception of decreasing current through the bulb. In this context, the participants confused energy and current. According to the responses in this study, it is clear that since the understanding of the misconceptions is limited, that might lead the participants to be unable to assist the learners to understand the concepts related to current, charge, electric field, and energy in an electric circuit.

Question 3 establishes the participants' knowledge of voltage. The parallel branches have the same voltage (Buchla & Floyd, 2020). Half of the participants chose the correct option which indicates the knowledge of the voltage. Half of them have a challenge regarding voltage. It is congruent with the study that was conducted by (Gaigher & Moodley, 2017) which found that half of the participants knew the voltage and the other half lacked that knowledge.

Question 4 establishes the participants' knowledge of the series circuit arrangement of bulbs. The responses of the participants indicate that three out of four participants answered this question correctly; however, two of them were confident about their answers which indicates their knowledge of the series circuit arrangement of the bulb. Only one out of four participants provided an incorrect answer but was confident about the answer which indicates the lack of knowledge about the series circuits arrangement of bulbs.

Question 5 focuses on the understanding of current being the same at any point in an electric circuit. Three out of four participants got the answer correctly; nonetheless, two participants guessed the answer and that was regarded as an incorrect answer, which indicates limited knowledge of misconception of the current being consumed in three out of four participants. One participant was a bit unsure which is an indication of limited knowledge. It implies that most participants have limited understanding in this regard. In this circuit, the current is the same at any point. The source of current supplies constant current to any load/resistor (Buchla & Floyd, 2020). This is congruent to a study that was conducted by (Marks, 2012) in which it was envisaged that the students know this concept; nevertheless, half of the students responded correctly to the question of current conservation. The reason for this challenge might be emanating from the confusion about the concept of current and energy which was also a finding in a study by (Preston, 2019).

Question 6 establishes teachers' knowledge of the circuit as a whole by depicting the second circuit diagram to resemble a parallel circuit. One participant got the answer correctly which is an indication of the knowledge of the circuit as a whole. Three participants chose the incorrect option thus most participants have limited knowledge of parallel circuits. A similar finding was pointed out in (Gaigher & Moodley, 2017) whereby four out of six students did not perform well in parallel circuits.

Question 7 seeks to establish the knowledge of the application of series circuits (open circuit). In electric circuits, the current flows via each component. The current flows if the path in an electric circuit is not broken (Kuphaldt, 2006). In this circuit, the flow of the current is interrupted since the circuit is open and other parts of the circuit are affected, hence the bulb will not light up. Three out of four participants got the answer correctly, which is an indication that most participants possess knowledge of broken circuits. Only one participant got it incorrectly which indicates limited knowledge of broken circuits. This contradicts the case of the students in the finding of the study which was conducted by (Kapotis et al., 2022) which indicated that removing a light bulb from the circuit poses a problem to students.

Question 8 establishes the knowledge of real series circuits. The three participants chose the correct option, and they were certain about the answer which is an indication that most participants know series circuits. One participant portrayed limited knowledge of series circuits.

Question 9 establishes teachers' knowledge of broken series circuits as a problem emanating from conceptual reasoning. Marks (2012) reiterates that a complete circuit is needed to light up the circuit. This sentiment is also shared by (Buchla & Floyd, 2020) when pointing out that when the lamp burns up, it results in an open circuit thus preventing the current in the series circuit. Three participants chose the correct option, and they were certain about the answer. This implies that most participants have knowledge of broken series circuits. Only one participant got the answer incorrectly. This is opposite to the study that was conducted by (Kapotis et al., 2022) that found that removing bulbs from the circuit poses a problem to students.

Question 10 establishes the teachers' knowledge of voltage in series and parallel circuits.
Three out of four participants got the answer incorrectly. One out of four participants chose the correct answer and was confident about it. This indicates that most participants misunderstand the concept of voltage in parallel and series circuits. The misconception is that the bulbs become

brighter if the batteries are connected in parallel as compared to a series connection in this case. This is congruent to a study conducted by (Engelhardt, 1997) in which the students thought that the two batteries in parallel supply more energy.

Question 11 determines the teachers' knowledge of resistance in a circuit. The electrical devices that consume energy should have a resistor (Edminister & Mahmood, 2018). This means in electric circuits; the resistors use up energy by changing it to another form. The electrical energy is changed to other forms of energy, for instance, with a light, if there is current within the resistance, it causes it to produce light (Buchla & Floyd, 2020). Two participants answered correctly. The participants were confident about their choice, an indication of the knowledge of resistance. Two participants chose an incorrect option. This indicates that half of the participants have knowledge of resistance. This relates to a study conducted by (Marks, 2012) in which the results show that the students focus on the current without paying attention to resistance.

Question 12 was to ascertain the teacher's knowledge of the unipolar model. Lin (2016) highlights that leaner without the comprehension of the complete path of the current portray unipolar model. This means the students have a unipolar misconception. According to (Gaigher & van der Merwe, 2011), the learners thought that the single wire in an electric circuit enables electricity to flow to the component which is a misconception. Demirci and Küçüközer (2007) point out the results related to simple circuits, including that the current as a unipolar model in which only one wire connects the battery and the bulb and the other wire to the bulb is not required for the light to light up. This is an indication that the bulb and one wire allow the current to flow across the circuit which is incorrect. On the contrary, in this study, the participants have knowledge of the unipolar model, unlike the physics teachers in studies as pointed out by (Demirci & Küçüközer, 2007).

5.3 Research question 2 findings and interpretation: What is the nature of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits?

The TSPCK assessment tool questionnaire findings are discussed to answer research question 2.

5. 3.1 Category 1: Learner's prior knowledge and misconceptions.

The teachers must know what the learner understands to have a picture with regards to the errors that need to be rectified because of existing understanding related to the new concept. Different studies emphasise the importance of prior knowledge when teaching learners. The results of the Technology subject study that was conducted by (Fahrman et al., 2019) indicate that teachers think that attempting methods and making errors is significant steps in enhancing the understanding of the learners. Azam (2019); (Boz & Can, 2014) also highlight the importance of prior knowledge. A study involving electric circuit misconceptions, (Taşlıdere, 2013) highlights that learners should have prior knowledge before engaging in a new concept; if the new concept is acceptable, then it can be incorporated together with the old one.

Bryan and Stuessy (2006) highlight the electric circuit concepts that are misunderstood by the students, including current, potential difference and power resistance energy; the students use the concept of brightness instead of current or voltage. This indicates the prevalence of these misconceptions. For the participant to answer question 1.1, the participant should have included these concepts in their explanations. Kocakülah and Küçüközer (2007) highlight simple electric circuits misconception, including the consumption of current (Kocakülah & Küçüközer, 2007). This means the teacher should have this knowledge of misconception to understand learners' misconceptions.

In question 1.1, the participants portrayed limited knowledge of learner prior knowledge and misconceptions since the responses to this question indicate that the participants could not pinpoint the electric circuits' prior knowledge or misconception. They could not relate their explanations to different misconceptions in this question. This is congruent to what was revealed in a study by (Kocakülah & Küçüközer, 2007) when nearly all participants portrayed a misconception of the current that decreases when flowing through the bulb due to the bulb lighting up. On the other hand, (Gaigher & van der Merwe, 2011) found that the teachers were aware of the learners' understanding of the attenuation model/weakening current model.

The power supply as a constant current source is regarded as a misconception (Gaigher & van der Merwe, 2011). The learner prior knowledge or misconception of the battery as a constant source of electric current was not included in the participants' explanations. This correlates with different studies that were conducted by other researchers, including (Kocakülah & Küçüközer, 2007) whose findings denoted that the students had misconceptions in this regard. The misconception of constant current sources was comprehended by only one teacher out of three teachers in a study that was conducted by (Gaigher & van der Merwe, 2011). Bryan and Stuessy (2006) study also pointed out that elementary teachers thought that the battery was a source of current for the current to be constant across the circuit. This shows that the teachers still have a limited understanding of the misconception of the attenuation model as well as the battery as a constant source, and some confuse the terms energy and current.

In question 1.2, the participants were expected to choose the teacher's feedback to illustrate their understanding of the learner prior knowledge and misconceptions. Examples of the misconception that could be included are power supply as a constant source of current, bulbs in series always emit more brightness and parallel bulbs emit more light than series bulbs. The question was related to the brightness of the bulb/lamp when connected in series and parallel considering the power supply. The study by (Suchai & Thasaneeya, 2012) revealed the misconceptions related to light bulbs include that the brightness of similar light bulbs that are connected in a series circuit is not the same. In this study, all the participants did not point out these misconceptions yet the study that was conducted by (Marks, 2012) found that pupils think that the number of the batteries increases brightness of the bulb and posited that this is correct if the batteries are connected in series yet incorrect if the batteries are connected in parallel. The study that was conducted by (Kocakülah & Küçüközer, 2007) revealed for the first time in the literature the misconception that the parallel bulbs in a circuit are brighter than the bulbs in a series all the time. In this study, the participants could not choose the most relevant answer with explanation and misconception.

The overall findings of this study in category 1 learner's preconceptions and misconceptions showed that the participants have limited knowledge of learners' misconceptions of electric circuits which concurs with other studies in the literature. Khwanda and Molefe (2019) found that their study was congruent with previous studies in that teaching electric circuits for qualitative understanding is a problem for students/leaners from secondary to tertiary levels. Teachers without the comprehension of learners' misconceptions might find it difficult to mitigate these misconceptions, hence this might be beneficial to investigate the perception of teaching electricity with regards to their understanding of learners' misconceptions since that knowledge might be valuable in teacher development and teacher training (Gaigher & Moodley, 2017).

5.3.2 Category 2: Curriculum saliency

Curriculum saliency implies the knowledge that is possessed by the teacher about what should be included or excluded when teaching the topic: the significance of the concepts, the rank in which the concepts can be taught and also the connection amongst the concepts (Coetzee et al., 2018); the comprehension of the topics that are taught prior and post the topic; and the significance of teaching the topic and what to teach (Mavhunga & Rollnick, 2017). This means the knowledge of curriculum saliency is required when teaching because it is this knowledge that enables the teacher to select what should be taught, decide on the main concepts and the secondary concepts surrounding the main concepts and rank the concepts or topics. The teacher should know the concepts to be taught before and after the topic.

Mavhunga and Rollnick (2017) articulate that curricular saliency entails determining the big ideas for teaching the topic; big ideas are regarded as significant when starting to teach the topic; big ideas are assertions articulating the main concepts of the topic; big ideas are associated with other ideas of a topic and how to rank them in teaching. This indicates that the teacher's knowledge of the topic is broken down into main ideas that are taught in a certain order; the big ideas should not be confused with the topic since they are the key ideas that are taught.

This implies that the knowledge of curriculum saliency is vital since it indicates what knowledge the teacher must have when teaching a certain topic; without this knowledge, it will be difficult to teach the topics of electric circuits. The teacher will not know the main ideas (big ideas), and the teacher will not be able to ascertain the concept that should be taught in electric circuits. Besides, the teacher will not be able to establish the order in which the concepts should be taught; the concepts linked with the big idea that are understood by the teacher need to be ascertained.

The teachers should possess knowledge of the content related to electric circuit concepts when they employ the curriculum. To teach the content, the teachers should be able to use related teaching approaches. For the teachers to succeed in the implementation of the curriculum, they are required to have the knowledge of content, learning teaching approaches, education technologies, teaching methods techniques and evaluation approaches and be able to implement them in learning and teaching to accomplish the necessities of the present curriculum (Cesur et al., 2017). They continue to denote that teacher should practise the curriculum that is established; the teachers ought to provide feedback about the curriculum to enhance it.

Oliver (2007) articulates that the curriculum in isolation cannot offer the information that is required by the teachers to render learning a fruitful experience for the learners, and this involves considerations, including prior knowledge, group collaboration, student ideas and explanations and instructional techniques.

In this study, category 2 has four questions (2.1. 2.2, 2.3, 2.4). question 2.1 required the participants to list the basic and central concepts (big ideas) when teaching electric circuits, for instance, a battery generates an electric field within the materials that make up the circuit, the electric field brings about the current to flow; electric circuits as system wherein the changes in one part of the circuit can impact the other, the current.

Different studies identified the big ideas that are related to electric circuits, including current, resistance, voltage difference, electric circuit closed loop, current production, circuit controlling the current and battery. Aktan (2012) mentions the central and subordinate ideas, including current, resistance and voltage difference. Zimmerman (2015) also draws attention to the big ideas, including that the battery generates an electric field within the materials that make up the circuit, the electric field brings about the current to flow and electric circuits as a system that changes in one part of the circuit can impact other parts. Marks (2012) points out the basic ideas that should be comprehended with regards to the functionality of the simple electric circuit closed loop, how the current is produced, resistance and how it controls the current, battery and potential difference. Marks (2012) indicates that these ideas should be integrated in a circuit to be considered a system with all parts functioning together whereby if one part of the circuit is altered, the whole circuit is impacted or altered. All participants could not identify big ideas. This is an indication of limited knowledge of the big ideas. A study that was undertaken by (Zimmerman, 2015) also found that the respondents were having a problem of identifying the big ideas related to electric circuits.

Question 2. 2 required the participants to sequence the big ideas**.** In all participants' responses, the sequence was not possible since the ideas that were provided were not big ideas. This indicates that the participants have limited knowledge of sequencing the big ideas in electric circuits. This correlates with the findings in a study that was conducted by (Zimmerman, 2015), where the respondents had a problem of sequencing the big ideas.

In question 2.3, the participants were required to show the interconnection between the big ideas and subordinate ideas to ascertain the knowledge of the curriculum, for instance, subordinate ideas linked to electric system (one part affects other parts, and energy is needed in a system in order for the current to flow; electric current needs a continuous loop for it is a net flow of charge; charge comes from the materials in a circuit; and a battery provides energy as a result of electric field). Besides, proficiency of the teacher in identifying the curriculum links horizontally and vertically. Azam et al. (2019) assert that the knowledge of the curriculum focuses on the comprehension of the Science curriculum by considering the topic, and it involves the proficiency of the teacher in identifying that the curriculum links horizontally and vertically. This highlights the need to establish the teachers' knowledge of connecting the big ideas with subordinate ideas.

In this study, only one participant provided subordinate ideas without linking them to big ideas. The other ideas that were regarded as subordinate included what supplies the circuit with energy, the electric circuit and current which were not subordinate ideas. This is an indication that the participants had limited knowledge in this regard. This challenge was also found in a study by (Zimmerman, 2015) who found that there was no association between the most significant idea to a subordinate idea. This indicated limited knowledge of the participants to link the electric circuits.

In question 2.4, the participants were expected to portray their knowledge of the importance of electric circuits. Electric circuits are important since they are found in different devices and are used for different purposes. Electric circuits are widely utilised in nowadays devices, for instance, computers, phones, cameras and others (Cossio, 2016). It was vital to include the question of the importance of the circuits.

In this study, one participant was able to identify the importance and of electric circuits in our daily lives to a certain extent, hence their knowledge is limited. This is contradictory to a study that was conducted by (Zimmerman, 2015) in which the explanation of why it is important to teach electric circuits was the least problematic.

Overall, the curriculum saliency category indicates that the participants are at the limited level which is congruent to (Zimmerman, 2015)'s study in which the participants portrayed limited knowledge in this category. Contrary to a study that was conducted by (Ibrahim et al., 2016), the findings revealed that preservice teachers obtained exemplary ratings. The preservice teachers improved in two quality categories of this component after an intervention.

5.3.3 Category 3: Difficult ideas to teach electric circuits.

Studies that involve the knowledge of the difficulties that are experienced by the learners are required. Studies of this nature have been conducted focusing on certain concepts and topics. Some of these studies paid attention to electric circuits. Kapotis et al. (2022) reiterate that the various studies show the difficulties and problems in the study of DC electric circuits, and these studies are still being conducted. This sentiment is shared by other studies. Makhechane and Mavhunga (2021) also articulate that the knowledge of learners' difficulties and preconceptions is gaining insight into the concepts that require exclusive consideration and focus when the topic is taught. That is why this component was included in this study.

The study that was conducted by (Marks, 2012) focusing on teaching and learning of basic ideas regarding electricity reiterates that the difficulties emanate from teaching or abstract concepts that the learner has to deal with; the teachers might not be equipped/ready to teach the topic in a way that is not difficult for the student to comprehend; and may be the teachers were experiencing the challenge regarding the topic when they were students.

The teacher comes to teach with his or her previous experiences; that means if the teacher is still struggling with the concepts and lacks the knowledge of difficult ideas experienced by the learners, this might result in learning in which the students do not get the most out of it, and this will account for learning difficulties that the student comes across with (Dewati et al., 2019). That would mean the teacher would not be able to tackle the electric concepts or topic proficiently when teaching in a way that hinders the student’s comprehension of the concepts.

For the teachers to teach proficiently, they need to know the ideas that are difficult to teach. This makes it clear that the abstract nature of electricity or teaching could create difficulties when the learners learn electricity. This is echoed by (Mark, 2012) by stating that the impact of the current and the flowing charges in wires and the reasons for that are abstract, forming mental imagination of resistance, controlling the current jointly with the battery, the potential difference that could be difficult to achieve. Besides, (Dewati et al., 2019) add to the list the electrical voltage, electric resistance, direct current law, calculating power, electrical energy in series and parallel DC electrical circuits.

It means that if the learners have difficulties due to deficient comprehension of concepts, the teacher lacks the knowledge of the learners' difficulties, hence it will be impossible to mitigate the challenges experienced by the learners. If the teacher possesses this knowledge, the learners will be able to grasp the concepts linked to voltage, resistance, current, power, energy, circuits (parallel and series), power and electric energy.

This category establishes the teachers' knowledge of the concepts that are difficult for the learners. Question 3.1 required the participants to portray their knowledge or understanding of concepts that are difficult for the learners.

In this study, the participants identified difficult concepts, including cells and batteries, circuits, paths for transmitting electric current and electric circuit material that provides charged particles if electric current is present. The reasons that were pointed out for the concepts to be difficult is that the learners need to understand different concepts, including charged particles. Another reason is that there are too many concepts to be understood at one go, but the participant did not indicate those concepts. If the current is available in a circuit, the energy flows from the battery to the external circuit. The knowledge of the teachers in this category is basic.

The concepts that are difficult were also pointed out in other studies. The findings of this study are congruent with some difficult ideas that are mentioned in a study that was conducted by (Dewati et al., 2019), where it was revealed that the students have limited understanding of the concepts, including potential differences, obstacles, electric current flowing in a series or parallel circuit, electric power and energy and understanding Ohm's and Kirchhoff's laws.

5.3.4 Category: 4 Representations

The representation is a form of epistemological foundation of reasoning (Brassard et al., 1999). This means that in order to understand the concepts, the representation helps to create a mental picture of an abstract concept like electric circuits, hence it is important for the teacher to have knowledge of representations. Fenwick and Unsworth (2022) articulate that visual and written representations are needed considering curriculum and pedagogy. This emphasises that these representations should be used when teaching.

The representations related to learners' experiences of invisible electric concepts using circuit diagrams should be considered before recognised representations of electric circuits. Even (Lombard & Simayi, 2019) suggest that teachers must strengthen learner experiences with representations before presenting invisible disciplinary recognised representations, for instance, the circuit diagram.

Different examples of representations are listed in different studies, including the representations that could be utilised by the technology teacher like analogies and illustrations (Hlatshwayo et al., 2022); diagrams of electric circuits for teaching and assessment (Preston, 2019); and demonstration, video, analogy, simulation and/ diagram to support the explanation of a certain concept (Coetzee, Gaigher, & Rollnic, 2020). Mainali (2021) denotes that using multiple kinds of representations improves teaching and learning, for instance, verbal (text, symbols, and sentences), graphic (drawings, pictures), numeric and algebraic. This means the electric circuits too could be visualised using representations in the form of drawings, electric circuits, simulations, diagrams, graphs, symbols, text, drawings, pictures, numerics, illustrations and analogies to simplify the concepts for the learners.

In Question 4.1, the participants had to choose the analogy they like and the one they dislike and give the reason why they like or dislike it. Different representations are available in research, including the ones that are associated with water pumps, batteries in electric circuits and turning the tap to release more water. The quantity of water flowing through a pipe is the current; if the tap is turned more, the pressure increases and the water coming out increases.

All the four participants indicated what they liked about the representations, but some could not clearly indicate the reason for disliking the representations. This is congruent with what was found in a study that was conducted by (Zimmerman, 2015) that revealed that the teachers were able to provide their views about the representations they liked and the ones that they did not like. The participants are at developing level.

Question 4.2 focused on how the participants could use the representation chosen from the representations provided. Three participants are at a developing level, hence the overall rating for question 4.2 is developing since the participants have some knowledge of the representations.

The overall rating of this category is developing. This correlates with the study that was conducted by (Coetzee, Gaigher, & Mazibe, 2020), where it was found that the preservice teachers' knowledge of representation rating is developing. On the contrary, post-graduate preservice teachers and postgraduate teachers portrayed weak knowledge of representations even after intervention (Makhechane & Mavhunga, 2021). In a study that was conducted by (Ibrahim et al., 2016), four preservice teachers portrayed the most improved achievement of representations. The representations contribute to the enhancement of concept acquisition which depends on the teaching strategies.

5.3.5 Category 5: Conceptual teaching strategies of electric circuits

This category is establishing teachers' knowledge of teaching strategies. Oliver (2007) reiterates that the information that is needed by the teachers to provide learning involves pre-conception, learners' ideas and explanations, the concepts, pre-concept, and ideas stipulated by the curriculum.

The objective of the curriculum is to develop the students with regards to qualitative comprehension of simple circuits voltage and resistance since the students tend to struggle with these concepts (Burde & Wilhelm, 2020). For the learners to comprehend the concepts in the curriculum, the teacher should be knowing these concepts held by the learner.

Category 5 consisted of questions 5.1, 5.2 and 5.3. In question 5. 1, the participants were able to indicate what the learner knows, for instance, electricity, battery, current, charge and negative and positive terminal. Nonetheless, they did not indicate the explanation about the current, as well as the misconception of energy and the current. This is congruent to other studies in which the same challenges were noted. Kautz and Timmermann (2013) research revealed that the students experience difficulty regarding comprehension of fundamental concepts of current and voltage. In a study conducted by (Preston, 2019), the student conceptual models were energy instead of current based, and this has electricity instruction repercussions at the primary level.

In this question, it is evident that the learner confused the current to energy by thinking that the current is used up which is a misconception. The teacher should have the knowledge of students relating to concepts of current and energy and voltage for them to teach the electric circuits with meaning.

Question 5.2 identifies the gaps that the learner is having. The gaps were represented by the wrong answer of the learner. The learner thinks that the current is used up in an electric circuit which is a misconception. The electrons are not mentioned by the learner or energy conversion. The learner is mixing up the concept of charge/current and energy. The learner did not mention the concepts, including that the battery provides the current; it is energy that is used up in electric circuits, charge versus energy and electrons.

These gaps are highlighted in other studies. A study that was conducted by (Bradley et al., 2019) found that the student teachers think that the cell supplies current and that the current is consumed in the circuit; the students do not have a mental picture of electrons being conserved as they drift around the circuit. In this study, two participants could not identify the concept gaps of the learner. One participant in this study mentioned the gaps, including electricity, battery, energy and current without explanation. One participant was confusing the concept of the current being consumed.

In a study that was conducted by (Zimmerman, 2015), the gap that was identified is how the current flows in a circuit considering the battery, electrons with energy and electric energy. This is congruent to the conceptual gaps identified in this study, for instance, current and energy. The gaps that are identified in teaching and learning require to be mitigated to improve the performance of the learners.

In question 5. 3, the participants were required to come up with strategies to mitigate the gaps that were identified. Bradley et al. (2019) highlight that more studies focus on teaching strategies and teacher conceptions. Oliver (2007) articulates that the curriculum involves instructional techniques. It implies that the instructional technique contributes to the implementation of the curriculum which involves, for example, abstract electric circuit concepts. The instructional strategy could lead to concept difficulties. The motive behind the learning difficulties is discouraging methods, teacher talk and teaching itself (Mark, 2012).

The teaching strategies play a major role in ensuring that those abstract concepts are mediated in a manner that makes them easy to be comprehended by the learners, therefore, the teacher should know strategies that are relevant when teaching the concepts of electric circuits, including current, energy, battery, series, and parallel circuits. This is affirmed by (Corod & Mendoza, 2022) when stating that the emphasis should be based on improving strategies that will assist the students and distinguish core concepts and theories that will help in remembering and efficient learning.

The different studies denote the various strategies that could be used when teaching, including practicals, using representations and construction models. In a study that was conducted by (Fahrman et al., 2019), the results revealed that the teachers express their teaching as practically involving hands-on tasks, and while the teacher helps the learners, they (teachers) express how the practical activities are selected. Nonetheless, the practically oriented teaching approach is time consuming**.**

The study that was conducted by (Kapotis et al., 2022) found that the traditional approach (laboratory) to circuits results in conceptual and reasoning hindrances, and it does not assist the students to deal with difficulties. In this study, it is argued that in Technology, the approach of assembling the electrical circuits in a workshop is still relevant because that resembles what is done even in industries, and the learners could see electrical components, especially because qualitative analysis is not easy. Working in the workshop is fun for the learners; nevertheless, this approach could be used in conjunction with other approaches, for instance, simulations and virtual labs.

The representations assist by shedding light with regards to the content/concepts that are abstract to the learners and the different scholars assert this sentiment and provide examples of representations. The representations involve how the teachers clarify the content and allow the learners to advance with regards to knowledge and understanding; the representations involve the illustrations, simulations, examples, models, analogies and metaphors; they assist the learners to understand certain concepts and relationships, for instance, demonstrations, investigations, experiments and assignments (Fahrman et al., 2019). Gaigher and Moodley (2017) suggest demonstration to mitigate the errors or impart information thus strengthening their ideas.

In a research that was conducted by (Tan, 2017), the teaching strategies that were recommended include cooperative learning strategies and the provision of a safe learning environment, emphasising critical thinking skills and allowing students to understand the content and do well examinations. Using peer collaboration, computer programmes and class discussions can be effective in guiding students through conceptual change, but only if they are willing (Oliver, 2007)**.** In a study that was conducted by (Corod & Mendoza, 2022), the proposed learning strategies are learning activities, hand on activities, and they further reiterate that the teachers are required to establish different instructional strategies concerning prior knowledge that allows the students to negotiate beliefs and new information.

The strategies that are indicated by the participants in this study include revision, teacher-directed strategy, asking questions, telling the learners about charge, using representation when teaching circuit components, games, quizzes, and body modelling. These strategies are congruent with what was pointed out in other studies, for instance, using representation as a strategy (modelling) but teacher-directed/telling the learners is discouraged. Even (Eromosele & Onojerena, 2018) assert that some teachers are still obstinate to teacher centredness irrespective of the advantages of learner centred teaching, and they propose that the government must hire qualified teachers with essential language, content in pedagogical skills utilising the learner centred teaching methods. This study concurs with this sentiment, the in-service development programmes should be strengthened and focused on teaching strategies to improve the performance of the learners.

5.3.6 Category 6: Teaching resources for electric circuits

The resources enhance teaching and learning which can make difficult abstract electric circuits concepts easy by providing world experiences, therefore the teachers should know the resources. The study that was conducted by (Lockley & Williams, 2012) asserts this sentiment since it discovered that the resources are required, and they bring real-world exercises of chemistry topics that could be taught. The resource allows the teacher to teach effectively. Kind (2007) also affirms this by pointing out that the resources enrich teacher efficacy and equipment, and books and other materials increase learning prospects in the classroom.

Various resources could be used in teaching. Different scholars indicate examples of resources, including written and visual texts (Fenwick & Unsworth, 2022). As much as different resources could be used, (Fahrman et al., 2015) bring to attention the factors that can hinder the utilisation of the resources in Technology, including limited teaching time that does not allow the teacher to adapt teaching, and it may hinder the use of the resources efficiently.

The teacher imparts what is learnt through the teaching strategies that they use and change to offer learning opportunities, for instance, electric circuits. The resources make what is learnt easy and enable the learners to comprehend what is taught.

The resources that participants pointed out in this study when teaching electric circuits include the textbooks, Sasol Inzalo workbooks, pictures of electric circuits, charts of electric circuits, analogies, and electric circuits model. Elaboration on how the participants use these resources is not indicated. Some of these resources were highlighted in other studies, for instance, written and visual texts. Some participants also indicated that there is a shortage of resources. Teaching is determined by resources. This is evident in this study because the teachers indicated the resources they use when teaching electric circuits, which is aligned with what is highlighted by (Petrina, 2007) as it pointed out that instructional strategies or teaching methods rely on resources.

5.3.7 Category 7: Technologies for teaching electric circuits

Technology is defined by different scholars differently. Fan and Mailizar (2019) define technology as how to utilise ICT as well as software-related peripherals. Angeli and Valanides (2015) regard ICT knowledge as understanding how to utilise a computer (tools and software) and the tool deliverables.

The teacher needs to have knowledge of ICT. According to (Fan & Mailizar, 2019), ICT knowledge involves tablets/mobile devices, laptops/computers, software animation, general software knowledge, word processor software (e.g., Ms Word), presentation software (e.g., Ms PowerPoint), online presentation software (e.g., Prezi), spreadsheet software (e.g., Ms Excel), mind mapping software (e.g., Inspiration), animation software (e.g., Macromedia Flash), three-dimensional visualisation software (e.g., Sketch Up), knowledge of online tools [online learning resources (Khan academy, youtube) and learning management system (e.g. Moodle)]. Ajredini et al. (2019) provide an example of PHET simulations which make the concepts of electric circuits visible. Ishak and Rosli (2022) study found out that the use of virtual labs could enhance teaching and learning, and video simulations could enhance teachers' knowledge of experiments.

It means the teacher may use this knowledge to incorporate ICT when teaching electric circuits. It could capture learners' interests and clarify some abstract concepts and may improve learner achievement. The different studies concur with the sentiment that ICT can improve performance. Bansilal and Mutambara (2022) reiterate that technology could be utilised to expedite teaching and learning and contribute to learners' attainment. This is also echoed in a study by (Harindintwari et al., 2019) which revealed that ICT utilisation could be regarded as a suitable example to be employed in developing countries since they need to align their education system to the general development. The result of the study that was conducted by (Anam et al., 2022) shows that in public and private secondary schools, there is a necessity to make sure that computer studies or ICT instruction allows the students to obtain the required ICT skills for appropriate performance in the post-Covid-19 period. ICT in education aids schools with limited and outdated library resources (Harindintwari et al., 2019).

It is significant for teachers to know the education technologies to enhance teaching and learning. This is motioned by (Cesur et al., 2017) when reiterating that teachers should know the education technologies in order to achieve the requisites of the curriculum. This is vital as a curriculum content administrative tool which is prevalent in educational organisations; it provides pedagogical innovations to classrooms, hence it is created to allow students to use computers effectively to expedite different academic activities and programmes (Anam et al., 2022).

The findings of this study revealed that the participants portrayed the knowledge of the following ICT resources, including a smartboard, laptop, router, YouTube video, Science websites, accessing workbooks and worksheets via WhatsApp, quizzes and using slides, projectors, and the cell phone. This is congruent to what was found in other studies, but the smartboard, WhatsApp and overhead projector to project slides was not mentioned in these other studies.

As much as most teachers in this study used technology to a certain degree, one participant is not using it at all. The participants pointed out some challenges, including a lack of technology gadgets like computers/laptops, tablets and overhead projectors and the unavailability of data and the challenge of internet connectivity. This is congruent to other studies, for instance, the barriers in Nigeria involve financial limitations, insufficient electricity, inadequate ICT resources and teacher incompetency in ICT tools to improve teaching and learning (Anam et al., 2022). In addition, (Bansilal et al., 2018) also posit that numerous schools cannot keep pace with well-equipped schools when incorporating ICT into their teaching and learning approaches.

5.3.8 Category 8: Learner diversity for inclusive teaching of electric circuits

Different scholars define inclusion. Malahlela (2017) defines inclusion as catering and supporting learner diversity in normal secondary schools. Inclusive education involves getting rid of barriers to learning and offering quality education to learners with learning challenges; these learners should be offered assistance considering their barriers; it must be perceived as a model of complete development changing and adapting attitudes of teachers to allow all learners to participate in the curriculum (Mahlo et al., 2017).

This implies that inclusivity accommodates different potentials since the learners come to school with different backgrounds; they come from different environments and have different interests, hence they must be all accommodated.

The inclusivity in this study focuses on the learners that are classified by (Mahlo et al., 2017) as the learners with learning difficulties without a reason and the learners with difficulties emanating from being underprivileged due to sociocultural factors, and these are found in the majority of classrooms, and they are the ones ignored.

The instruction that the teacher provides should accommodate the diverse abilities of the learners. Different groups of learners should be taught using differentiating the curriculum to accommodate and develop them to the best of their potential. This study focused on the learners that are found in the mainstream classroom. This category focused on language as a barrier in teaching electric circuits.

Nelson et al. (2010) highlight that the concepts that are taught to the learners should be taught using different methods, strategies and learning styles to ensure that all the learners are catered for and that all of them are benefitting from the learning opportunities. Inclusivity also involves structuring the pedagogy to transform what is supposed to be known, understood and could be done in a manner that accommodates participation for all (Baglier & Shapiro, 2017). (Mahlo et al., 2017) study concludes that teachers should understand, assist the learners, and use different ways of teaching since the learners possess different learning styles. This necessitates support regarding instruction that the teacher provides considering the abilities of an individual (Leuders et al., 2021).

Language is the medium that conveys the content and knowledge, hence developed language capabilities and language skills are necessary for learning to take place; if the language of teaching is a challenge it could lead to failure (Mahlo et al., 2017). This indicates that language skills should be developed because without the necessary vocabulary and skills, it will be difficult for the learner to grasp what is presented when they learn electric circuits.

In question 8.1 of this study, the participants were able to identify the correct EAC skills, including listening and speaking, reading, and viewing and writing and presenting. They are at the developing level.

In question 8.2, the participants were able to incorporate EAC skills when teaching electric circuits by allowing the learners to view pictures, drawings, symbols, charts, and electric components, but speaking, presenting, and reading were not clearly explained in terms of how they are implemented when teaching electric circuits. This study did not find the study that focused on this category highlighting the teachers' knowledge regarding diversity for inclusive teaching electric circuits.

5.3.9 Category 9: Assessing electric circuits

Imenda and Oyinloye (2019) regard assessment as one of the tools accessible to be utilised in education for various purposes, including maximizing learning, motivating the students, enhancing their performance, and realising the pre-specified goals and standards. It has helped the teachers to ascertain the learner achievement by way of conducting internal quizzes, period tests and final examinations. This implies that assessment is crucial since it is used to culminate learning, encouraging the students, and advancing learners' performance using quizzes, tests, and examinations.

In a study conducted by (Imenda & Oyinloye, 2019), the results indicated that when incorporating and employing the assessment for learning, an instructional approach improved the performance of the learners; classroom assessment should be conducted on an ongoing basis to enhance instruction; the learners should be certain that they can all succeed when they learn.

According to the results of (Fahrman et al., 2019)'s , study written tests, assignments and reports are utilised as summative assessments to reinforce the subject. Jones and Moreland (2000) found that assessment was not procedural and conceptual; formative assessment focused on generic skills instead of student technological understanding. The findings of this study correlate with the other studies since in this study, the participants indicated the use of weekly tests, quizzes, practicals, pictures, short tests and baseline and diagnostic assessment. This indicates that the teachers portrayed the knowledge of formative and summative assessment. However, a study by (Barendsen & Henze, 2017) revealed that the idea of conceptual check questions fitting within the teacher's lecturing was the main instructional strategy and formative assessment was rare.

5.3.10 Category 10: Various contexts in which teaching electric circuits takes place

The context influences the way the teachers teach due to the context the teacher can teach effectively or inefficiently. Angeli and Valanides (2015) reiterate that in various contexts, the contextual factors differ considering classrooms, schools districts and countries that enhance or inhibit the ability of the teachers to utilise what they acquired in professional development. According to (Kind, 2007), there are contextual barriers even in university teaching, including teaching in large classes, time limits, a shortage of resources, attitudes and tenure of students and promotion issues. In addition, other scholars highlight these factors. For instance, (Petrina, 2007) highlights the issues on which instructional strategies rely on, including environment, time, physical settings and resources. Angeli and Valanides (2015) posit that the contextual factors differ in schools and districts, and they influence planning and instruction. Contextual factors such as the time for planning, collaboration instruction, administration and accessing resources, as well as regional constraints affect decision making for instruction.

The rating of this category indicates that the teachers have basic knowledge of various contexts in which teaching electric circuits takes place. The contextual factors that were indicated by the participants include the contextual multigrading setting, a shortage of resources due to funding, unavailability of the resources such as bulbs and switches, a shortage of space in the classroom to assemble circuits and community as a factor determining the exposure of the learners to devices that use circuits and how they work. Some of these contextual factors relate to other studies, for instance, accessing resources.

5.4 Summary of findings

In this study, some good practices, gaps when teaching electric circuits were identified. The summary of findings is presented according to three research questions.

5.4.1 Research question 1 findings and interpretation: What is the level of grade 7 teachers' content knowledge when teaching electric circuits?

Research question 1 provided insight into the teacher's content knowledge. Most teachers have limited knowledge of the conservation of charge, energy, and parallel cells in a circuit. Most teachers have knowledge of series circuits, conservation of current, consideration of a circuit as a whole, open circuit in series and schematic and circuit diagram of series circuits. Some teachers know voltage and resistance. All the teachers know the unipolar model. The teachers have the basic CK. This indicates that they need more support in conservation of charge, energy, and parallel cells in a circuit. The CK of the teachers could be enhanced.

5.4.2 Research question 2: What is the nature of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits?

Research question 2 provided insight into the TSPCK of teachers. The teachers have limited knowledge of learner prior knowledge and misconceptions of electric circuits. In curriculum saliency, the teachers portrayed limited knowledge of big ideas, sequencing of big ideas and linking big ideas and subordinate ideas as well as the importance of the electric circuits in daily life.

The teachers have the developing knowledge of the learner's difficulties when teaching electric circuits. The teachers know representations since the rating is developing. With regards to conceptual teaching strategies, some teachers have the knowledge of energy and the current, and most could not identify the learner's gaps. Some teachers have basic knowledge of what the learners know; most teachers have limited knowledge of the learner's knowledge gaps; most teachers have basic knowledge of the teaching strategies. Most teachers have basic knowledge, and one is having the developing knowledge of the teaching resources.

The teachers have developing knowledge of some ICT resources. Nonetheless, in other cases, how to use the resources was not indicated clearly. The teachers have the knowledge of ICT skills, but not all of them were able to indicate clearly how to implement it when teaching electric circuits. The teachers have a developing knowledge of formative and summative assessment. The teachers have the basic knowledge of various contexts in which teaching electric circuits takes place. The teachers have developing knowledge of learner diversity for inclusive teaching of electric circuits. The teachers have developing knowledge of representations.

In this study, the TSPCK knowledge of the teachers was established through the responses in different categories of the TSPCK questionnaire. It was evident that the teacher's knowledge is developing in TSCK categories, representations, assessing electric circuits and learner diversity for inclusive teaching of electric circuits, basic in categories including difficult ideas to teach electric circuits, teaching resources for electric circuits, technologies for teaching electric circuits, conceptual teaching strategies of electric circuits and various contexts in which teaching electric circuits takes place, limited in categories curriculum saliency and learner prior knowledge and misconception.

There is no teacher with an exemplary level of TSPCK. The overall TSPCK of the teachers is developing. This is an indication that teachers still need support with regards to the learner prior knowledge and misconception and curriculum saliency which was performed poorly and the categories that were performed at basic levels.

5.4.3 Research question 3: What is the correlation between grade 7 teachers' content knowledge and topic specific pedagogical content knowledge when teaching electric circuits?

The Pearson product moment correlation in this study is 0, 301511 which indicates a weak positive correlation. It is not the case that if the CK increases the TSPCK increases. The results of the study that was conducted by (Zimmerman, 2015) are congruent with this study since the correlation was 0.453 with limited value predicting CK based on TSPCK. The regression relationship in these variables, CK and TSPCK, was established, which CK does not always predict/portray TSPCK. This indicates that if the teachers could be supported with regards to content knowledge, which might also contribute to the enhancement of their TSPCK.

5. 5 Recommendations

The study focused on getting an insight into the teacher's TSPCK, and this necessitated the teacher development programme to alleviate the gaps in teachers' TSPCK.

Teacher development could be workshops structured in such a way that they focus on the TSPCK components that still need to be strengthened for instance the categories that were achieved at basic and limited levels. This can improve teachers' practices. These workshops could take place before the beginning of the term in which electric circuits are taught.

The teachers' TSPCK is at the developing level, but they can be supported to enhance some components of their TSPCK at basic and limited levels. The different components of TSPCK were achieved at different levels. In the case of TSPCK, the workshops could focus on conceptual teaching strategies of electric circuits, various contexts in which teaching electric circuits takes place, teaching resources for electric circuits, curriculum saliency, technologies for teaching electric circuits and learner prior knowledge and misconception, what is difficult to teach. The teachers' CK is basic, necessitating more support on some concepts. In the case of CK, the workshops should focus on the concepts, including conservation of charge, energy, parallel cells in a circuit, voltage, and resistance.

5.7 Future research

Technology subject is still regarded as a new subject, hence there is a need of conducting more research. Taking cognisance of this study, there is a need for research involving TSPCK and CK. The focus of TSPCK could be on components including conceptual teaching strategies of electric circuits, various contexts in which teaching electric circuits takes place, technologies for teaching electric circuits, curriculum saliency, learner diversity for inclusive teaching of electric circuits and learner's prior knowledge and misconception. In the case of CK, the research could focus on the concepts, including conservation of charge, energy, parallel cells in a circuit, voltage, and resistance.

5.8 Conclusion

This study focused on the knowledge of teachers' CK and TSPCK when teaching electric circuits as well as the relationship between CK and TSPCK, as data were analysed qualitatively and quantitatively and revealed that the TSPCK knowledge of teachers is at developing level; CK of the teachers is at basic level; the correlation between CK and TSPCK is 0,301511 which is a weak positive correlation. CK predict TSPCK however the relationship is weak in this study. It is not always that CK predicts TSPCK. Low levels of CK can related to low levels of TSPCK (Davidowits & Potgieter, 2016). This indicates that CK predicts TSPCK.

The reflection points out the use and impact of statistics of research question 3 and adaptation of TSPCK framework. When reflecting on research question 3 of this study the correlation between CK and TSPCK is weak positive. This might be due to small size of the sample. Various studies involving CK and TSPCK were conducted. Some studies found that the correlation between CK and TSPCK was positive. The study conducted by (Davidowits & Potgieter, 2016) result indicated 0.66 correlation between teachers' and TSPCK portraying positive CK and TSPCK correlation. They further assert that results concur with the notion that CK is necessary for TSPCK improvement, but it is not related to high TSPCK levels.

Davidowits, Potgieter & Rollnick (2017) study found that the correlation was 0,54 and added that the teachers with good CK are prone to have high levels of TSPCK, whereas the teachers having low levels of CK might have low levels of TSPCK. When reflecting on research question 3 of this study the correlation between CK and TSPCK is weak positive. This might be due to small size of the sample.

The researcher was doing the study related to TSPCK framework for the first time. Technology studies focusing on TSPCK when teaching electric circuits were not available. The literature related to TSPCK in Technology is limited. I was difficult to get the literature that addresses what was envisaged in this study hence the conceptual framework emanated from different components of TSPCK as pointed out in different studies in addition to components as stipulated by (Mavhunga, 2013). The researcher is involved in monitoring the implementation of different strategies by Technology teachers to improve the performance of the leaners. Some of these strategies involve the teacher to have the knowledge to accommodate diversity when teaching, implementation Technology when teaching and this necessitated the inclusion of the component involving the knowledge of ICT.

Since the context plays a role when teaching it was important to include the component related to knowledge of different contexts. The knowledge of assessment is required when the teachers teach hence it was important to understand this component. The teachers use the resources to teach, thus it was of significance to understand the teachers' knowledge in this regard. The inclusion of the additional components might have had the impact in on weak positive correlation between CK and TSPCK.

The recommendations included workshops in electric circuits. Future research needs to focus on TSPCK and CK concepts when teaching electric circuits.

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ANNEXURES

Annexure 1: Gatekeepers letter

KWAZULU-NATAL PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

Private Bag X9137, PIETERMARITZBURG, 3200
Anton Lembede Building, 247 Burger Street, Pietermaritzburg, 3201
Tel: 033 392 1051
Email: buyi.ntuli@kzndoe.gov.za

Enquiries: Buyi Ntuli **Ref.:**2/4/8/7248

Ms Millicent Khanyile
1 Hazelview
76 Hazeldene Road
SEA VIEW
4094

Dear Ms Khanyile

TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"AN EXPLORATION OF THE GRADE 7 TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE WHEN TEACHING ELECTRIC CIRCUITS AT LOWER UMVOTI CIRCUIT OF THE ILEMBE DISTRICT OF KWAZULU-NATAL:"**, in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from **17 March 2022 to 31 March 2025**.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

ILEMBE DISTRICT

[redacted]

Mr GN Ngcobo
Head of Department: Education
Date: 17 March 2022

Annexure 2: School's permission to conduct the research

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

COLLEGE OF HUMANITIES

MASTERS/PHD RESEARCH PROPOSAL AND ETHICAL CLEARANCE APPLICATION

(HUMAN AND SOCIAL SCIENCES)

To Whom It May Concern:

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AS PART OF THE REQUIREMENTS FOR THE AWARD OF A MASTER'S IN TECHNOLOGY EDUCATION QUALIFICATION.

It is a requirement of my master's qualification to undertake a research project. Typically, this project necessitates data gathering by means of Questionnaires. I have chosen to do a research project titled: An exploration of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits at Lower Umvoti circuit of the Ilembe district of Kwazulu-Natal

Your assistance in permitting access to your organisation for purposes of this research is most appreciated. Please be assured that all information gained from the research will be treated with the utmost circumspection. The researcher will strictly adhere to confidentiality and anonymity.

My academic supervisor is Mr M.P. Moodley at the college of Humanities, Edgewood campus, University of KwaZulu-Natal. Mr M.P. Moodley can be contacted on Moodleym1@ukzn.ac.za or telephonically on +27 31 260 3655, Edgewood Campus, Pinetown, Durban. He is available at any stage to answer any queries and/or to discuss any aspect of this research project.

You may also contact the Research Office through:

HSSREC Research Office
Tel: 031 206 4557
Email: HSSREC@ukzn.ac.za

If permission is granted, please sign the section below.

Yours sincerely,

Millicent Khanyile
Cell number: 0[redacted]
Email address: [redacted]a

To whom It may concern

I the principal of____ hereby give permission to ____ (Name of student) to conduct research titled 'An exploration of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits at Lower Umvoti circuit of the Ilembe district of Kwazulu-Natal.' in my organisation. The name of my organisation is____.

The student May/May not use the name of the organisation in the research report.
Name of school principal________________________________

Signature__________________________________ Date: ____________________

Principal's Cell number:__________________________

School Stamp

Annexure 3: Participants' consent letters

School of Education, College of Humanities

University of Kwa-Zulu Natal

Edgewood Campus

Dear Participant

Informed Consent Letter

My name is **Millicent Khanyile** I am a Masters candidate studying at the University of KwaZulu-Natal, Edgewood campus, South Africa.

One of the requirements for the awarding of this degree is that I should undertake an approved research project leading to the submission of a thesis titled: An exploration of grade 7 teachers' topic specific pedagogical content knowledge when teaching electric circuits at lower Umvoti circuit of the Ilembe district of Kwazulu-Natal

To gather information, I will ask you to complete a few questionnaires; participate and submit as directed.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person but reported only as a population member's opinion.
- Each questionnaire will take 30 minutes to answer the questions.
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not to participate or stop participating in the research. You will not be penalised for taking such action.
- Your involvement is purely for academic purposes and there will be no financial benefits involved.

I can be contacted at:

Email: [redacted] Cell number: 0[redacted]

My academic supervisor Mr M.P. Moodley is located at the School of Education, Edgewood campus of the University of KwaZulu-Natal.

Contact details: Email: Moodleym1@ukzn.ac.za, Phone Number: 031 260 3655.

You may also contact the Research Office through:

HSSREC Research Office
Tel: 031 206 4557
Email: HSSREC@ukzn.ac.za

Thank you for your contribution to this research

Please complete the section below:

I……………………………………………………………… (Full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.
Signature of participant…………………………………

Annexure 4: CK assessment tool questionnaire.

CONTENT KNOWLEDGE ASSESSMENT TOOL

Instructions

- Use the answer sheet to answer questions.
- Answer all the multiple-choice questions that are provided.
- Indicate confidence level for each question (a bit unsure, completely sure, confident, bling guessing)
- The batteries and lamps/bulbs are identical.

Questions

1. Is the charge consumed by the light bulb/lamp when it produces light?

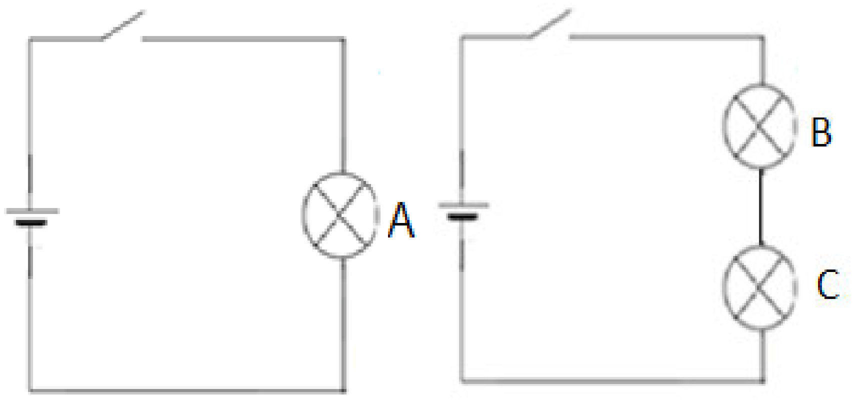
A. Yes, when the charge moves through the filament, friction is produced that generates that heat and the filament emits heat and light.

B Yes, the charges are produced.

C. No, the charge is not conserved, it is transformed into heat and light.

D. No, the charge is not consumed but it is conserved, the charge moves through the filament and creates friction that heats up the filament, and light is emitted.

2. How is the energy supplied to the bulb/lamp A in circuit 1 changed when the bulb/lamp B is added as indicated in circuits 1 and 2?



Circuit 1 **Circuit 2**

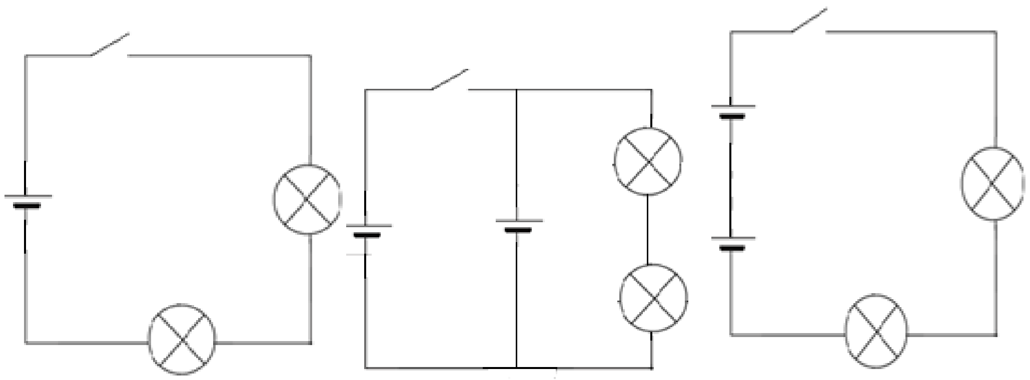
A. Lamp/Bulb A has least energy

B. Lamp/bulb B has least energy.

C. Lamp A and B have least energy.

D. Lamps B and C have least energy.

3. Choose the circuit that has the greatest energy that is supplied to it.



Circuit 1 Circuit 2 circuit 3

A. Circuit 1

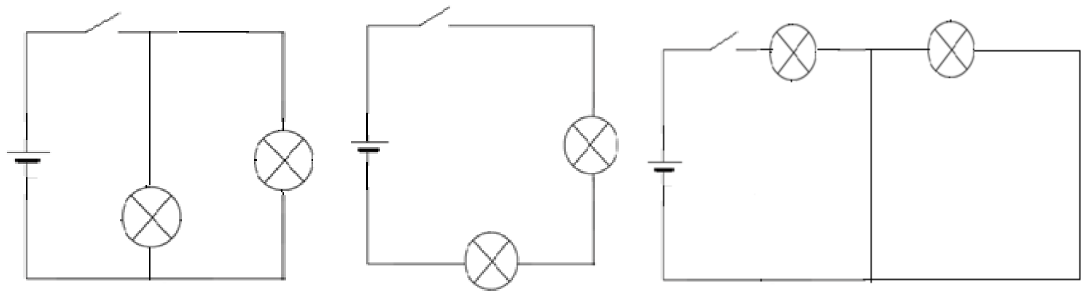
B. Circuit 2

C. Circuit 3

D. Circuits 1 and 2

E. Circuits 2 and 3

4. In the circuit/circuits provided below, identify the circuit/circuits that comprises of two light bulbs in series with a cell.



Circuit 1 Circuit 2 Circuit 3

A. Circuit 1

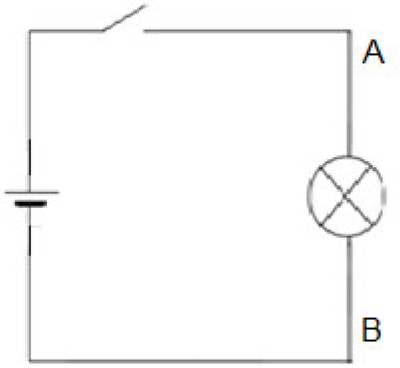
B. Circuit 2

C. Circuit 3

D. Circuits 1 and 2

E. Cicuits 1 and 3

5. Indicate the point that has the largest current



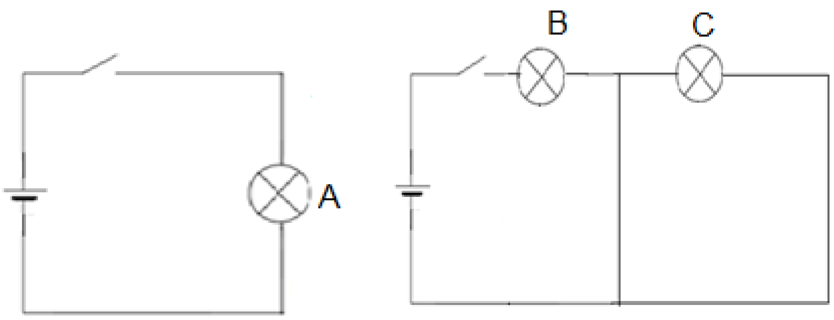
A. Point B

B. Point A

C. Either point A or point B

D. Neither point A nor point B, the current is the same in point A and Point B.

6. Which bulb or lamp will glow if the switches are closed?



A. A only

B. B only

C. A & B only

D. B & C

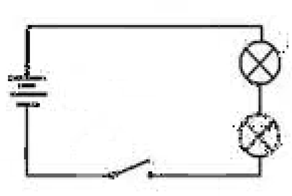
7. Why is series wiring of all the lights in the house not recommended?

A. Less charge will be released and the lights will dim

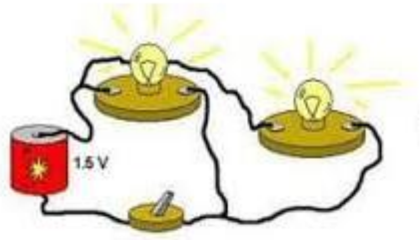
B. If one light fails that would cause all lights to go dark.

C. The current will be stored and the lights will go dark.

8. Choose the schematic diagram that is represented by the circuit diagram that is provided below if the switch is closed. Schematic diagram 1 and 2 are provided.



Circuit 1.



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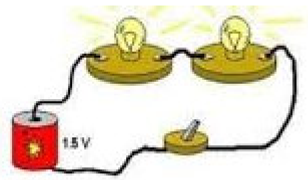
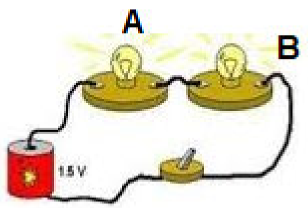
Circuit 2.



https://www.google.com.

A. Circuits 1
B. Circuit 2
C. Circuits 1 & 2
D. None of the above.

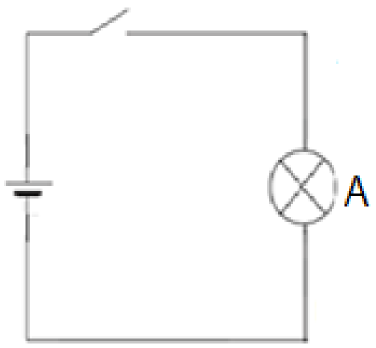
9. The circuit diagram with 2 bulbs is provided below. What will happen to bulb B if bulb A is removed?



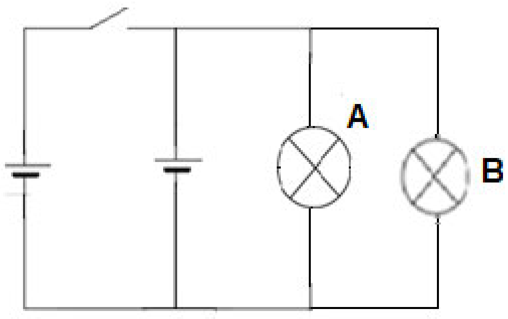
https://www.google.com.

A. Bulb will light up.
B. Bulb current will be reduced but still light up.
C. Bulb B current will be increased since there is only one bulb that is consuming the current.
D. The current will not reach light B

10. The circuit diagrams are provided below . Identify the bulb/lamp with decreased brightness if bulb A in circuit 1 is compared to bulb A in circuit 2.



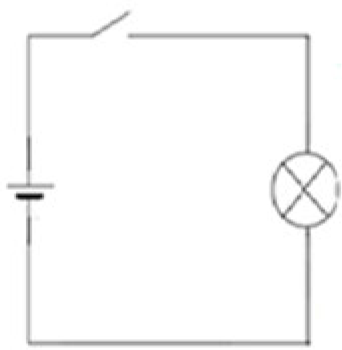
Circuit 1



Circuit 2

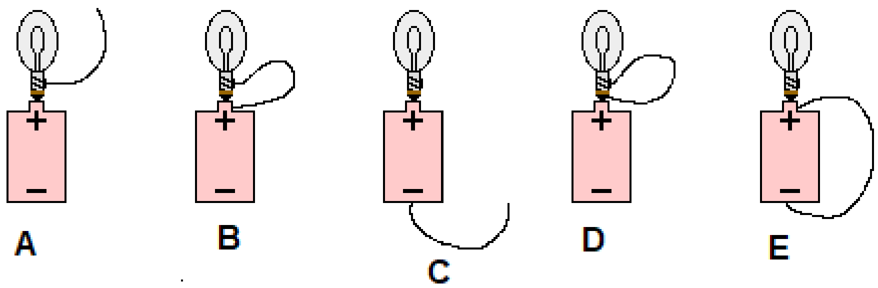
A. Bulb/lamp A in circuit 1
B. Bulb/lamp A in circuit 2
C. Neither A in circuit 1 nor A in circuit 2, the brighness is the same.

11. If the switch is closed what happens to the resistance of the bulb/lamp in the circuit diagram below?



A. The resistance decreases.
B. The resistance increases.
C. The resistance of the bulb/lamp remains the same.
D. There is no resistance.

12. Identify the circuit or circuits with the bulb that will light up.



https://www.google.com.

A. Circuits A&B

B. Circuits C&D

C. Circuits B&D

D. Circuit E

E. All bulbs will not light up

Annexure 5: CK assessment tool questionnaire memorandum

CONTENT KNOWLEDGE ASSESSMENT TOOL QUESTIONNAIRE MEMORANDUM

Total Score: 12

1. **D√**
2. **D√**
3. **C√**
4. **B√**
5. **D√**
6. **C√**
7. **B√**
8. **B √**
9. **D√**
10. **C√**
11. **B√**
12. **E √**

Note: The participants are required to choose confidence levels. Confidence levels minimise guessing the answers. The answer sheet was used to indicate their responses.

Confidence levels -a bit unsure, completely sure, confident, bling guessing

Annexure 6: Topic Specific Pedagogical Content Knowledge Assessment Tool Questionnaire

TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE ASSESSMENT TOOL QUESTIONNAIRE

Surname and Names:

Dear participant thanks you for agreeing to participate in this study. The questions are provided in this questionnaire. You are requested to answer all the questions. Please try to be as honest as possible as you answer the questions since it is your views and your experiences that count in this study. The data collected will be used for the research study only. The purpose of this research is to get an insight in terms of the grade 7 teachers' topic specific pedagogical knowledge when teaching electric circuits. The TSPCK assessment tool comprises of ten categories of questions.

Category 1 – Learner prior knowledge and misconceptions.

Category: 2 – Curriculum saliency.

Category 3 - Difficult ideas to teach in electric circuits.

Category 4 – Representations.

Category 5 - Conceptual teaching strategies of electric circuits,

Category 6 - Teaching resources for electric circuits.

Category 7 - Technologies for teaching electric circuits.

Category 8 - Learner's diversity for inclusive teaching of electric circuits.

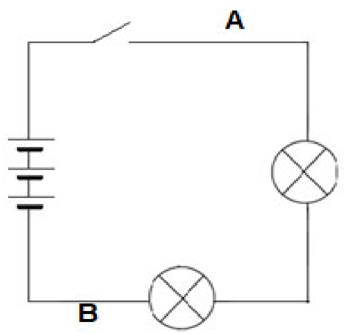
Category 9 - Assessing electric circuits.

Category 10 - Various contexts in which teaching electric circuits takes place.

QUESTIONS

Category 1 – Learner prior knowledge and misconceptions.

1.1 Study the circuit diagram below and answer the following question.



The following responses were provided by the learners if the electric circuit is **closed**. These answers were either correct or incorrect. The responses from the teacher are given below.

You are quired to choose the feedback or comment to learners' responses that you would probably use when teaching electric circuits and give the reason for your choice.

(i) The current in **B** is smaller than in **A.**

(ii) The current **A** is smaller than in **B**

(iii) The current in **A** is equal to **B**

Feedback/comments on leaners' responses

Choose the comment/feedback on the learners' responses (i) or (ii) or (iii)] that you would give to the learner and provide the reason/s in the space provided below.

Response A: The correct answer is (iii). The current does not split or divide since this is a series circuit. The current strength is the same throughout the circuit.

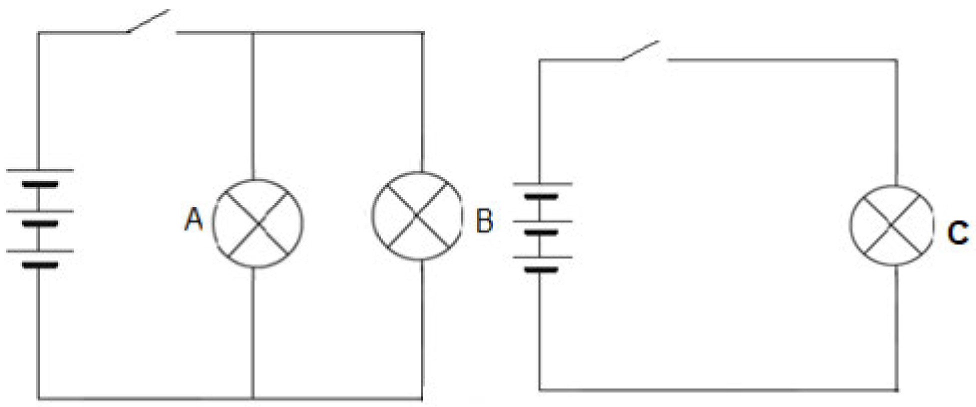
Response B: The correct answer is (iii). The rate at which the charge flows is called the current. It involves the movement of the electric charge carriers called electrons. The electrons move around the circuit, and they do not vanish in the electric circuit.

Response C: The correct answer is (iii). The rate at which the charge flows in an electric circuit is called a current. In an electric circuit, there is a flow of charge. The charge moves by means of a conductor. The charged particles move because of electric field that is produced by the battery and the particles that are charged are in the same electric field. The charge is the same across the electric circuit.

Response D: None of the above.

Select your response from the responses provided (A or B or C or D) and provide a reason for your choice in detail.	
Your choice:	The reason for your choice:

1.2 A grade 7 Technology learner was asked to compare the brightness of the lamp/bulb A in circuit 1 to lamp/bulb C in circuit 2 if the switches are closed and the lamps or bulbs are identical.



Circuit 1 **Circuit 2**

(i) The lamp/bulb A is brighter in circuit 1 than the lamp/bulb C in circuit 2.

(ii) The lamp/bulb C is brighter in circuit 2 than the lamp/bulb A in circuit 1.

(iii) The brightness of the lamp/bulb A in circuit 1 is the same as in lamp/bulb C in circuit 2

Feedback/ comments on leaners responses.

Response A: The number of lamps or bulbs in circuit 1 does not determine the brightness of the lamp or bulb in circuit 2. The brightness of the lamp is determined by the amount of current that is flowing through the lamp or bulb. In circuit 1, the brightness of the bulb A does not imply that the lamp or bulb will glow brighter than a bulb or lamp C in circuit 2. In circuit 1, the current is divided since the lamps are connected in parallel. The resistance of the lamps is halved, and the current is doubled hence the current is the same in parallel connection circuit 1 as compared to the brightness of the bulb or lamp in circuit 2. The current that is flowing through parallel branches circuit 1 is the same through each bulb hence the brightness is the same as compared to the brightness of the bulb circuit 2.

RESPONSE B: The bulbs are the same. The brightness of the bulbs is determined by how they change energy. In circuit 1 the current is doubled and halved in parallel connection hence the similar amount of the current is available to be changed. The resistance in circuit 2 is half the overall resistance.

RESPONSE C: In circuit 1, the bulbs are connected in parallel. There is division of current in parallel circuits. The resistance in bulbs or lamps is the same in parallel circuits hence the division of current is the same. The resistance is the same in parallel circuits. The two bulbs in parallel divide the resistance into halves and the current doubles, and the current is halved again at the parallel connections. The brightness of the lamps or bulbs is the same.

RESPONSE D: None of the above.

Select your response from the responses that are provided (A or B or C or D) and provide a reason for your choice in detail.	
Your choice:	The reason for your choice:

Category: 2 –Curriculum saliency

2.1 The content and concepts regarding the electric circuits are provided below. Choose and rank the three concepts that you consider basic and central concepts when teaching electric circuits.

(i) Closed and open circuits.

(ii) The net flow of charge is called an electric current

(iii) The circuit in which the electrons flow in one pathway is called a series circuit

(iv) The current flows through each component in a series circuit.

(v) In parallel circuits the current is divided.

(vi) The electric circuit materials provide the charged particles if the electric current is available.

(vii) The electric energy is supplied by the battery and the components that utilise the current include buzzers, bulbs/lamps, and conductor.

(viii) The battery generates an electric field in the materials that form the circuit. The electric field makes the current flow.

(ix) If the current is available in a circuit the energy flows from the battery to the external circuit.

(x) An electric circuit is the path for transmitting electric current.

(xi) An electric circuit is a system in which the transformation in one part can impact other parts.

CONCEPT
Concept 1
Concept 2

Concept 3

2. 2 Provide the sequence you would use to teach the concepts you have chosen in 2.1 and the reasons for choosing that sequence.

NO.	**Concept**	**Reasons for choosing this sequence**
1		
2		
3		

2. 3 Explain in detail how the concepts you chose in 2.2 interrelate. In your explanation also includes other subordinate concepts.

2.4 Why is it important for learners to learn electric circuits?

Category 3: Difficult ideas to teach electric circuits.

3.1 Identify the three electric circuits concepts that are difficult to teach the learners efficiently according to your experience and what do you think the reasons for this are. Write your response in the table below.

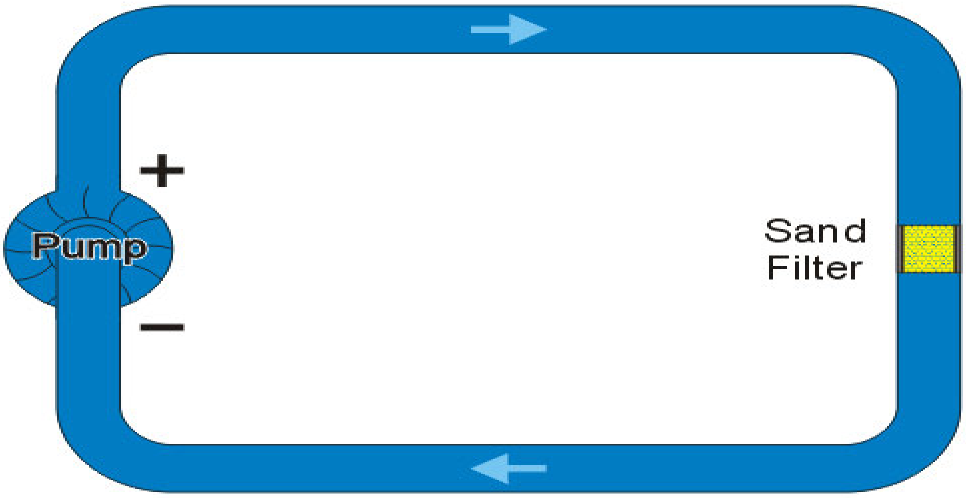
Concept	**What do you think the reasons are for this**
1	
2	

3	

Category 4 – Representations

4.1 The representations of teaching the concept of current are given. What do you like or dislike about each representation that is provided below? Provide the reason why one representation is better than another. Write you answer in the table provided.

Representation 1



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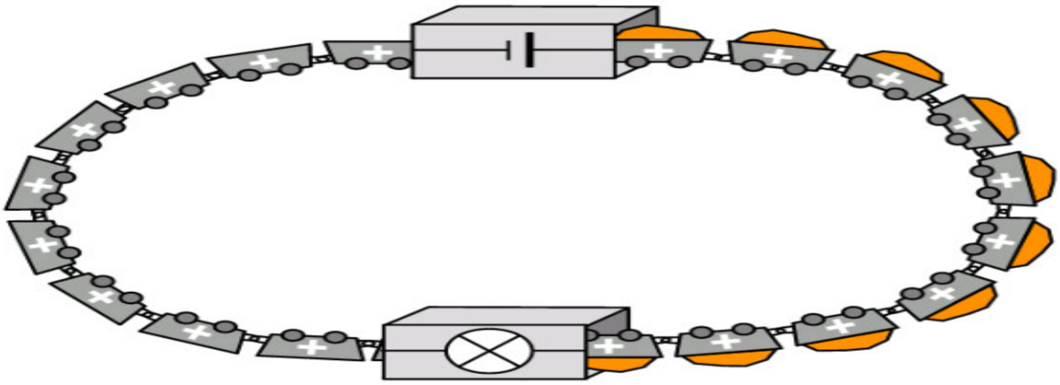
Representation 2



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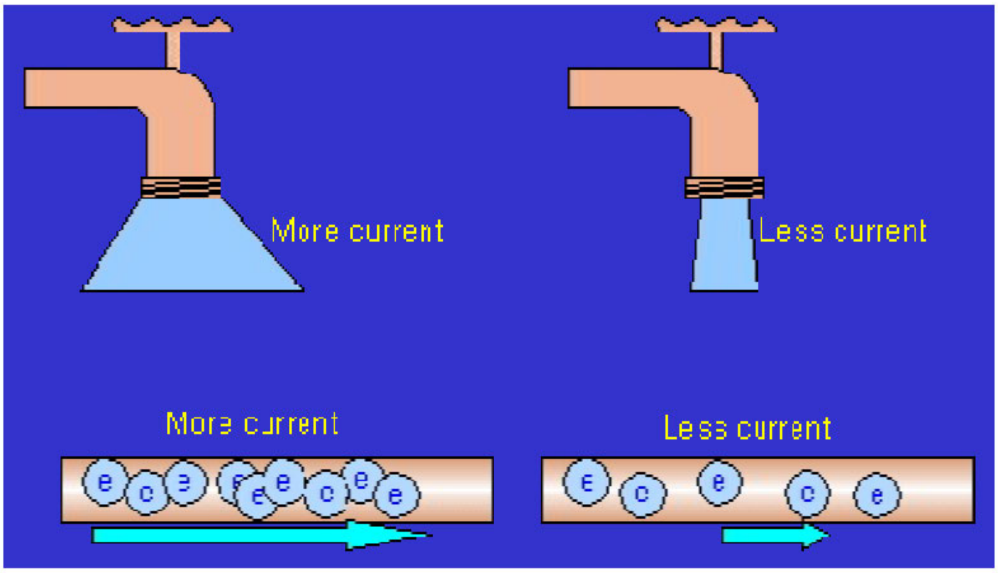
Representation 3



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Representation	What I like about each representation and the reason why I like it.	What I dislike about each representation and the reason why I like it.
Representation 1		
Representation 2		
Representation 3		

4.2 Identify the representation that you like the most among the ones that are indicated in 4.1 and how would you use these representations in a lesson.

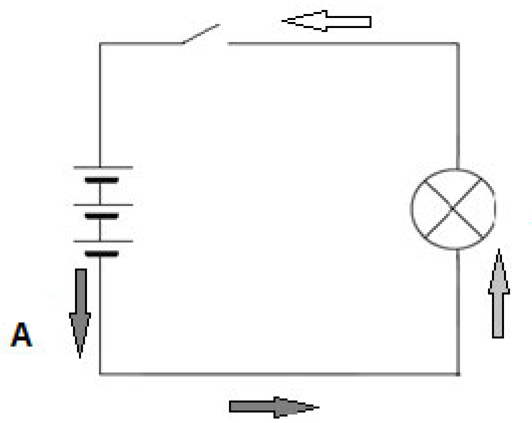
Representation I like the most.	**How would you use the representation selected in a lesson?**

Category 5: Conceptual teaching strategies of electric circuits

Examine the responses of the learners to a classroom activity below and explain the strategy that you would use to help the learners. Some of these responses are correct, and some are incorrect.

Activity

The following diagram shows the arrow leaving the battery full of energy at A if the circuit is closed. Answer the questions that follow.



(i) What is represented by the arrow?

Electricity

(ii) What is represented by the shaded part of the arrow?

Current

(iii) Where does the arrow get energy from?

Battery

(iv) What happens when the arrow moves from the positive terminal to the negative terminal of the cell?

The charge in the arrow is consumed.

(v) Is it correct to say that the electric current is consumed? Explain your answer.

Yes, the current is consumed because as it moves around the circuit, it gets used up as it produces heat and light, and by the time it gets back to the battery, all the current is finished.

5.1 What are the concepts that are known by this learner in the activity? Write your answer in the space provided.

5.2 What are the gaps with regards to concepts that are displayed by this learner in the activity? Write your response in the space provided.

5.3 What are teaching strategies you would use to bridge the gaps identified in 5.2. Write your answer in the space provided.

Category 6 - Teaching resources for electric circuits

6.1 How do you address the issue of resources when teaching electric circuits? Explain in detail. Write the answer in the space provided.

Category 7 - Technologies for teaching electric circuits

According to white paper on e-learning (Education, 2004), Information and Communication Technologies (ICT) should be implemented to enhance learning and teaching.

7.1 How do you use ICT when teaching electric circuits? Explain in detail. Write your answer in the space provided.

Category 8: Learner diversity for inclusive teaching of electric circuits

According to the guidelines for inclusive teaching and learning (Education, 2010), one of the barriers identified is the language and communication barrier since the language of teaching and learning is not the home language for some learners. The performance of the learners is also associated with the language of teaching and learning, and the Department of Basic Education introduced English across the curriculum strategy (EAC) to bridge the barrier of language of teaching and learning that is implemented in all content subjects, including Technology.

8.1 What are the 3 language skills that are supposed to be evident in the Technology lesson to address the issue of EAC when teaching electric circuits? Write the answer in the space provided.

8.2 How do you implement EAC when teaching electric circuits? Explain in detail. Write your answer in the space provided.

Category 9: Assessing electric circuits

9. 1 Explain in detail the methods you use to assess the learners' understanding of electric circuits.

Category: 10 Various contexts in which teaching electric circuits takes place.

10. 1 What are the contextual factors that impact the teaching of electric circuits? Explain in details. Write your answer in the space provided.

Annexure 7: TSPCK assessment tool rubric

TSPCK RUBRIC				
Category 1: Leaners prior knowledge and misconceptions				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
1.1	▪ Teacher recognises misconceptions or prior knowledge and provides a correct explanation to mitigate misconception. ▪ Provides standardised knowledge as definition and/or expands and re-phrases explanation correctly/with multilevel approach. • Explanation	▪ Teacher recognises misconception or prior knowledge and gives the correct explanations to mitigate misconceptions. ▪ Provides standardized knowledge as definition or expands and re-phrase explanation using single level explanation. ▪ Explanation of concepts is evident.	▪ Teacher recognizes misconception or prior knowledge without providing the explanation to mitigate the misconceptions. ▪ Repeats standardized knowledge as definitions and explanations without expansion. ▪ No or incorrect explanation of concepts	▪ No recognition of misconceptions and no provision of the explanation to mitigate misconception. ▪ No standardized knowledge as explanations and defining and explaining ▪ No or incorrect explanation of concepts

	demonstrates conceptual understanding.			

Category 1: Leaner prior knowledge and misconceptions				
Rating	**Exemplary**	**Developing**	**Basic**	**Limited**
1.2	▪ Teacher recognises misconceptions or prior knowledge and provides a correct explanation to mitigate misconception. ▪ Provides standardised knowledge as definition and/or expands and re-phrases explanation correctly/with multilevel approach. • Explanation demonstrates conceptual understanding.	▪ Teacher recognises misconception or prior knowledge and gives the correct explanations to mitigate misconceptions. ▪ Provides standardized knowledge as definition or expands and re-phrase explanation using single level explanation. ▪ Explanation of concepts is evident.	▪ Teacher recognizes misconception or prior knowledge without providing the explanation to mitigate the misconceptions. ▪ Repeats standardized knowledge as definitions and explanations without expansion. ▪ No or incorrect explanation of concepts	▪ No recognition of misconceptions and no provision of the explanation to mitigate misconception. ▪ No standardized knowledge as explanations and defining and explaining ▪ No or incorrect explanation of concepts

Category 2: Curriculum Saliency				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
2.1	Teacher recognises at least 3 big Ideas. (Any 3 from the list below) • Concept 1. (xi) Electric circuit is a system in which the transformation in one part can impact other parts. • Concept 2. (i) The net flow of charge is called the electric current. • Concept 3. (viii) The battery generates an electric field in the materials that form the circuit. The electric field makes the current flow.	▪ Teacher recognises at least 2 big Ideas.	▪ The teacher recognises at least 1 big Ideas	▪ The teacher does not recognise a big Idea

Category 2: Curriculum Saliency				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
2. 2	▪ Teacher provides logical sequence for all three big ideas ▪ Correct and logical reasons for sequencing the big ideas are provided and the link with other concepts is evident.	▪ Teacher provides linear sequence for the concepts. ▪ logical reasons for sequencing the big ideas are provided without link to other concepts.	▪ Suggested sequencing has illogical placing of big Ideas. ▪ The reasons that are given for sequence are unclear.	▪ Logical sequence is not evident. or the big ideas are mixed. ▪ Reasons for the sequence are not provided.

Category 2: Curriculum Saliency				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
2. 3	▪ Subordinate concepts are correctly identified for all big ideas with explanatory notes. ▪ The big ideas relate to subordinate concepts includes preconcepts.	▪ Identifies subordinate concepts correctly and shows links to big ideas with no additional information.	▪ Not all big ideas and subordinate concepts are identified but the identified ideas are correct.	▪ No identification of correct big ideas and

	▪ Identifies subordinate concepts focusing on understanding electric circuits concepts. ▪ Differentiate clearly and correctly the main subordinate concepts and minor concepts. ▪ Logical sequence and visual illustration of big ideas and subordinate concepts.	▪ Certain big idea is not indicated. ▪ Identifies subordinate concepts include application of circuits and concepts. ▪ Clearly differentiate the big idea and subordinate concepts. ▪ No visual illustration linking the big ideas and subordinate concepts.	▪ There are few connections between concepts and some connections not always correct. ▪ Some big ideas and subordinate concepts are not clearly differentiated. ▪ Subordinate concepts are limited to algorithms or standard definitions. ▪ Presentation of big ideas and subordinate concepts have the logical sequence and visually illustrating the electric concepts.	subordinate ideas. ▪ Not all big ideas have subordinate ideas ▪ Mainly incorrect or repetitions of big ideas with no connection with subordinate concepts. ▪ No correct connections between big ideas and subordinate concepts.

				▪ Big ideas and subordinate concepts are not clearly differentiated. ▪ Presentation of extensive ideas and subordinate concepts have no logical sequence and no visual illustration of electric concepts.

Category 2: Curriculum Saliency				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
2. 4	▪ Determines the importance of electric circuit considering application in daily life, motivation/interest and the logical reasons are provided adequately.	▪ Determines the importance of electric circuits related to its application to daily life, motivation/interest and some logical reasons are provided.	▪ Determines the importance of electric circuits related to its application to daily life and the inadequate reasons are provided	▪ General statements are provided without reasons.

Category 3: Difficult ideas to teach				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
3.1	▪ Identifies specific difficult concepts. ▪ Reasons link to other concepts and to TSPCK elements.	▪ Recognises specific difficult concepts. ▪ Reasons that are provided relate to one other TSPCK components.	▪ Recognises specific difficult concepts ▪ Provides general reasons	▪ Identifies general topics without specific challenging concepts.

			for the difficulty.	▪ reasons for difficulty are not provided.

Category 4: Representations				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
4.1	• Use of macroscopic representation or symbolic representation with sub-microscopic representation to enforce a specific aspect. ▪ Adequate explanations of representations(analogies) are linked to electric circuits concepts including numerous considerations. ▪ reasons involve misconceptions/or deficiencies of misconceptions	▪ Explanation of the representations (analogies) is linked to electric circuits to a certain extent. ▪ Reasons including considerations for instance user friendly, efficiency to deal with misconception, context. .	▪ explanation of representation (analogies) is not linked to electric circuits. ▪ Reason is limited	▪ explanation of representations (analogies) is not linked to electric circuits. ▪ Reasons are not specified, incomplete or not provided.

Category 4: Representations				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
4.2	▪ Utilization of representation (analogy) and the utilization of electric components with explanation incorporating different kinds of representations related to electric circuits.	▪ Utilization of representation (analogy) and the utilization of electric components with explanation related to electric circuits.	▪ Utilization of representation (analogy) and the utilization of electric components without explanation related to electric circuits	▪ Utilization of representation (analogy) related to electric circuits is not evident.

Category 5: Conceptual teaching strategies of electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
5.1	▪ Considers learner's prior knowledge and/or common misconception. ▪ Provided detailed explanation.	▪ Considers confirmation of learner prior knowledge and/or common misconceptions.	▪ Identifies learner's prior knowledge	▪ Incorrectly identification of learner's prior knowledge and/or misconceptions.

			▪ Misconceptions are not identified.	e. g differentiates between charge and current. ▪ No evidence of acknowledgement of learner's prior knowledge or misconceptions.

Category 5: Conceptual teaching strategies of electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
5.2	• Considers at least one aspect related to curriculum saliency e.g., sequencing or highlights important concepts. • Identifies areas of misconceptions.	• Considers at least one aspect related to curriculum saliency e.g., sequencing or emphasis of important concepts.	▪ Provide some aspects of curriculum saliency.	▪ Lacks aspect of curriculum saliency.

Category 5: Conceptual teaching strategies of electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
5.3	▪ Strategy is multidimensional it includes more than one possible strategy e. g analogy demonstration. ▪ Uses at least two different levels of representations to enforce understanding. ▪ There is evidence of self-reflection in their description of the strategy	▪ Uses at least two different representations (abstract and concrete) to enforce understanding. ▪ Provide detailed explanation.	▪ Utilizing the representations without related explanation	▪ No strategy is indicated. ▪ Irrelevant strategy is indicated.

Category 6: Teaching resources for electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
6.1	• Utilize different resources tangible, visual, text resources etc to enforce a specific aspect. • Clear link to other components of TSPCK, • Emphasis of core aspect of CK demonstrated by the resource.	• Utilization of resources tangible, visual text etc. with explanatory notes linking the two resources to the aspect(s) of the concept being explained. • Use of the resources combination with considering other TSPCK components.	Use of tangible resources, visual, text without explanatory notes to make connection with the aspects of the concept being explained.	Limited to use of only text, visual resources with no explanation of specific links to the concepts represented

Category 7: Technologies for teaching electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
7.1	• Utilization of technology to enforce a specific aspect. • Clear link to other components of TSPCK • Emphasis of core aspect of CK demonstrated.	• Use of technology with explanatory notes clarifying the aspect(s) of the concept being explained. • Use of combination of technology with reference to one other TSPCK components.	Use of technology without explanatory notes to make the links to the aspects of the concept being explained.	Limited or no use of technology with no explanation of specific links to the concepts represented

Category 8: Learner diversity for inclusive teaching of electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
8.1	▪ Identifies three EAC skills	▪ Identifies two EAC skill	▪ Identifies 1 EAC skill	▪ No EAC skill identified.

Category 8: Learner diversity for inclusive teaching of electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
8.2	▪ Uses EAC skills to enforce understanding of concepts. ▪ There is link with TSPCK components.	▪ Use of EAC skills with no linking explanatory notes ▪ there is a link with one other TSPCK components.	▪ Use EAC skills with no linking	▪ Use of EAC skills is limited or no correct

			explanatory notes	implementation of EAC skills.

Category 9: Assessing electric circuits				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
9.1	▪ Teacher defines assessment. ▪ Teacher identifies different forms of assessment/assessment strategies/assessment methods. ▪ Teacher explains how to assess when teaching electric circuits.	▪ Teacher identifies different forms of assessment/assessment strategies/ assessment methods. ▪ Teacher explains how to assess when teaching electric circuits.	▪ Teacher identifies different forms of assessment. ▪ Teacher does not explain adequately how to assess when teaching electric circuits.	▪ Teacher identifies different forms of assessment, assessment strategies, assessment methods. ▪ Teacher does not explain how to assess when teaching electric circuits.

Category 10: Various contexts in which teaching electric circuits takes place				
Rating	**Exemplary**	**Developing**	**Basic**	**limited**
10.1	▪ The teacher identifies the contextual factors when teaching electric circuits. ▪ Explains in detail how these factors impact teaching electric circuits. ▪ The explanation links with one or more TSPCK components.	▪ The teacher identifies the contextual factors when teaching electric circuits. ▪ Explains with notes how these factors impact teaching of electric circuits.	▪ The teacher identifies the contextual factors when teaching electric circuits. ▪ Explains with limited details/ notes how these factors impact teaching of electric circuits.	▪ The teacher identifies one or no contextual factor when teaching electric circuits. ▪ Explanation of how these factors impact the teaching of electric circuits is not clear.

Annexure 8: Declaration of editing research thesis

Registered with the South African Translators' Institute (SATI)

Reference number 1000686

SACE REGISTERED

17 July 2023

AN EXPLORATION OF GRADE 7 TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE WHEN TEACHING ELECTRIC CIRCUITS AT LOWER UMVOTI CIRCUIT OF THE ILEMBE DISTRICT OF KWAZULU-NATAL

This certificate confirms that I edited substantively the above document, including a Reference list. The text, as edited by me, is grammatically correct. The document was returned to the author with various suggestions and tracked changes from me intended to correct errors. After completion of my language editing, the author can accept or reject suggestions/changes before re-submission to the supervisor who will check the content and instances of plagiarism, if any.

Yours faithfully

[redacted]

Dr. K. Zano

Ph.D. in English

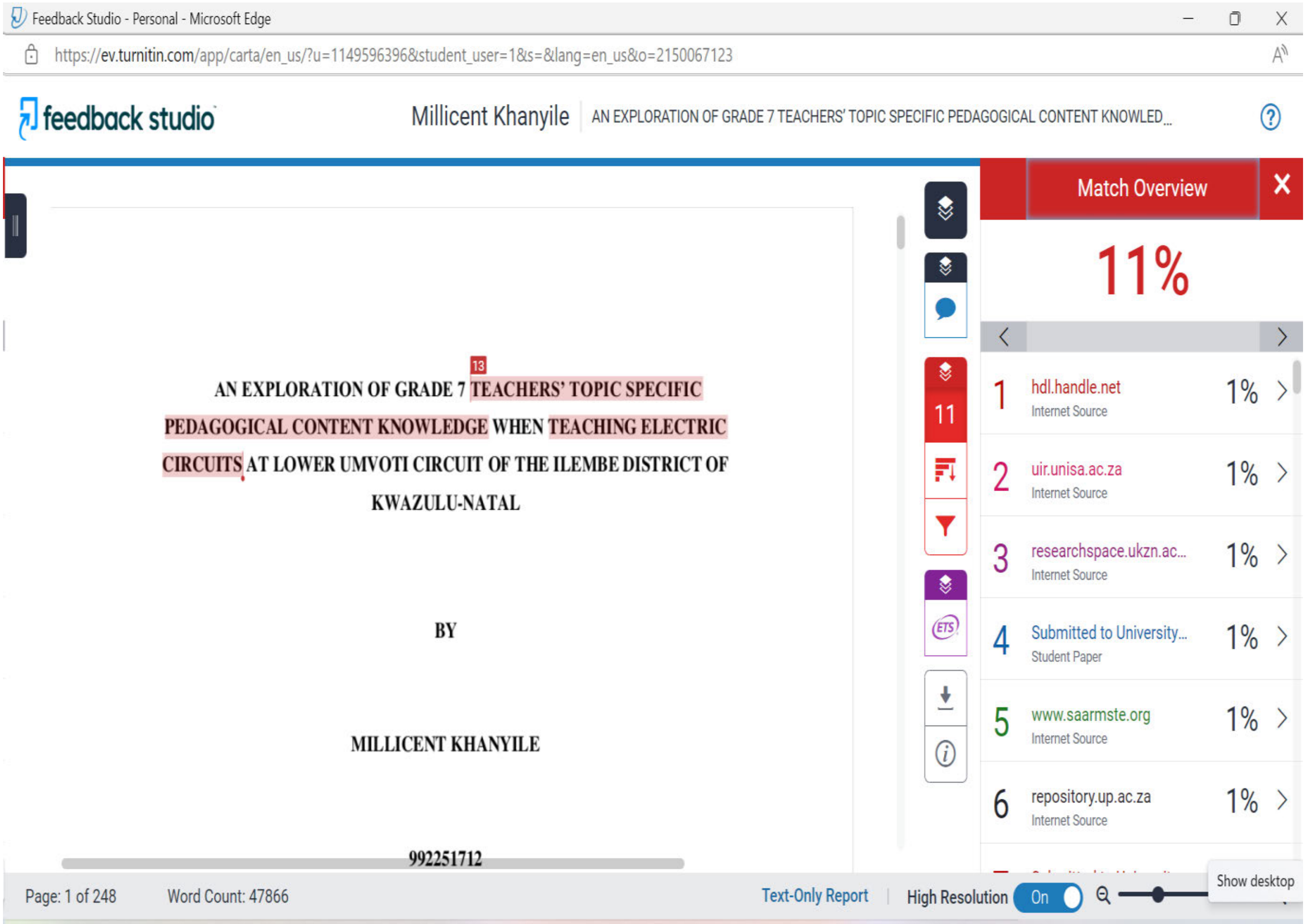
[redacted]

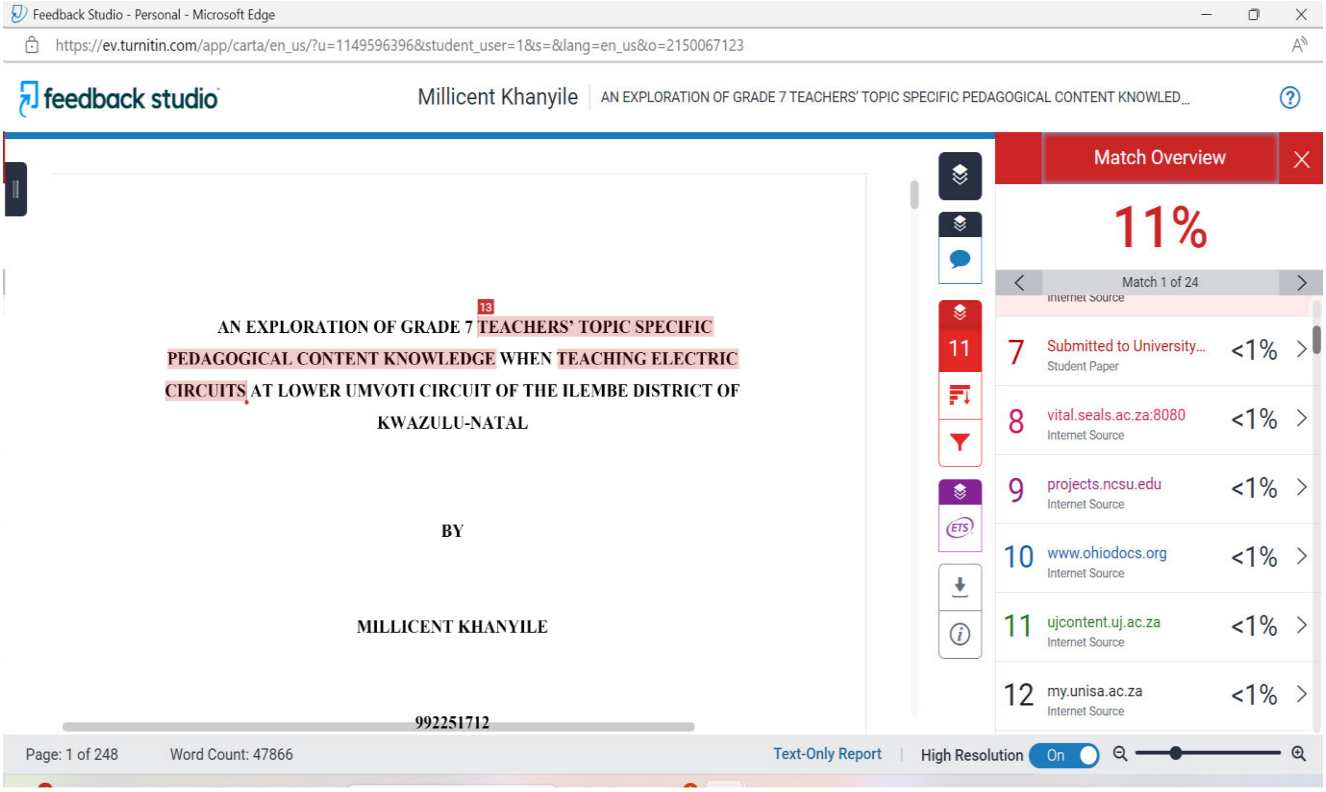
[redacted]

Annexure 9: CK assessment answer sheet

CONTENT KNOWLEDGE ASSESSMENT TOOL ANSWER SHEET **Name/S and Surname:**											
Question number	**Multiple choice answers (**indicate by putting (X) on the correct answer.						**Answer confidence level** (Indicate when answering the question whether you are a bit unsure, completely sure, confident, blind guessing. Put (X) the relevant level.)				
1	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
2	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
3	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
4	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
5	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
6	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
7	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
8	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
9	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
10	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
11	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
12	A	B	C	D	E		A bit unsure	Confident	Completely sure	Blind guess	
Total: **Average**:											

Annexure 10: Turnitin report

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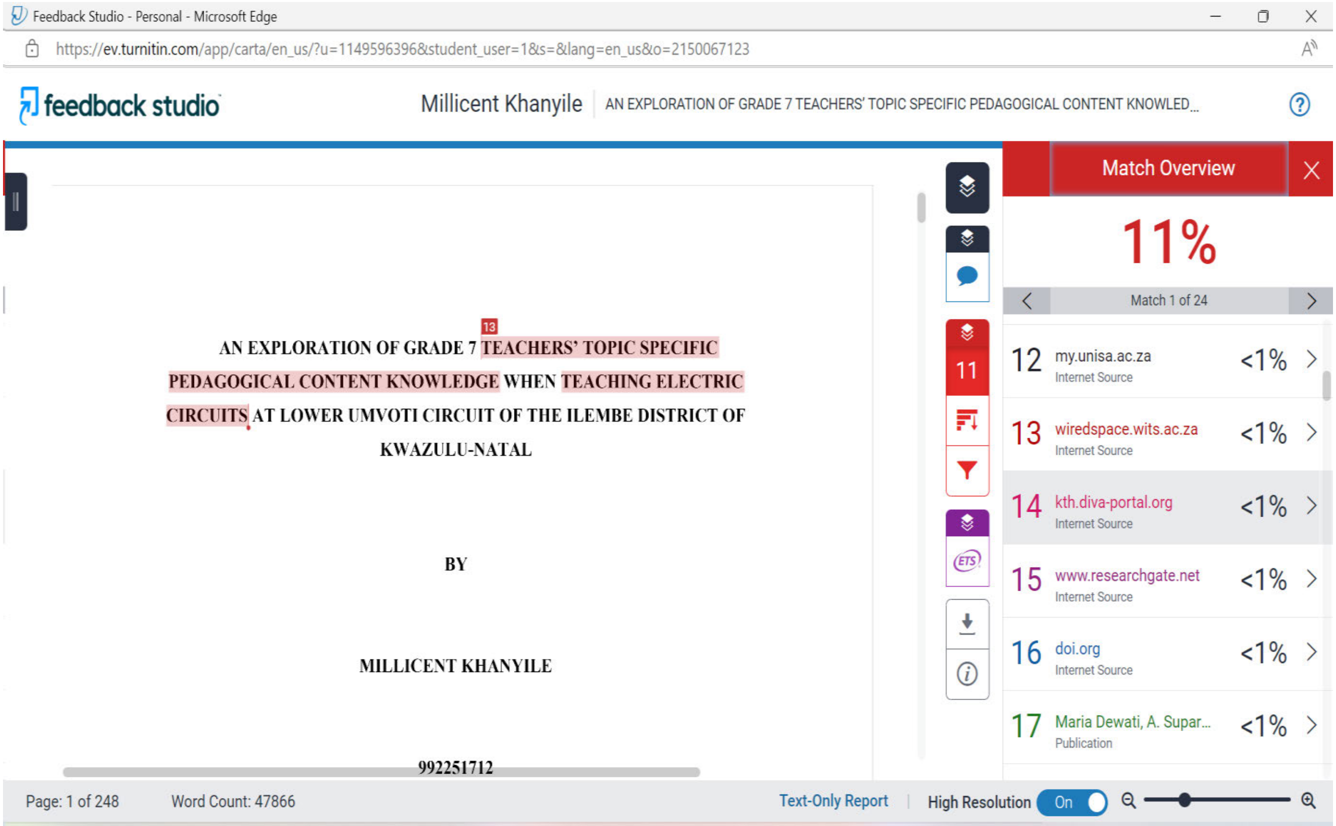
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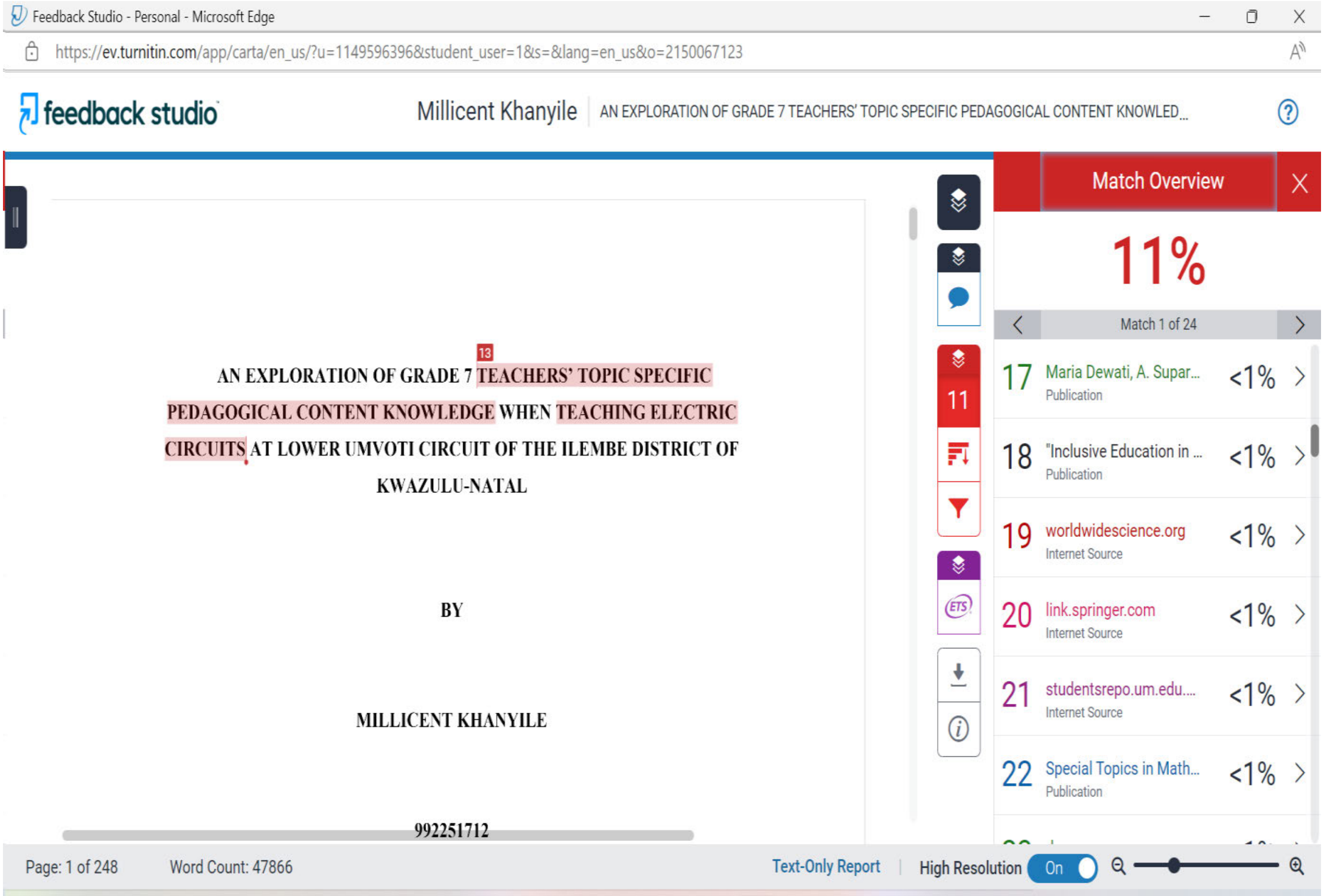

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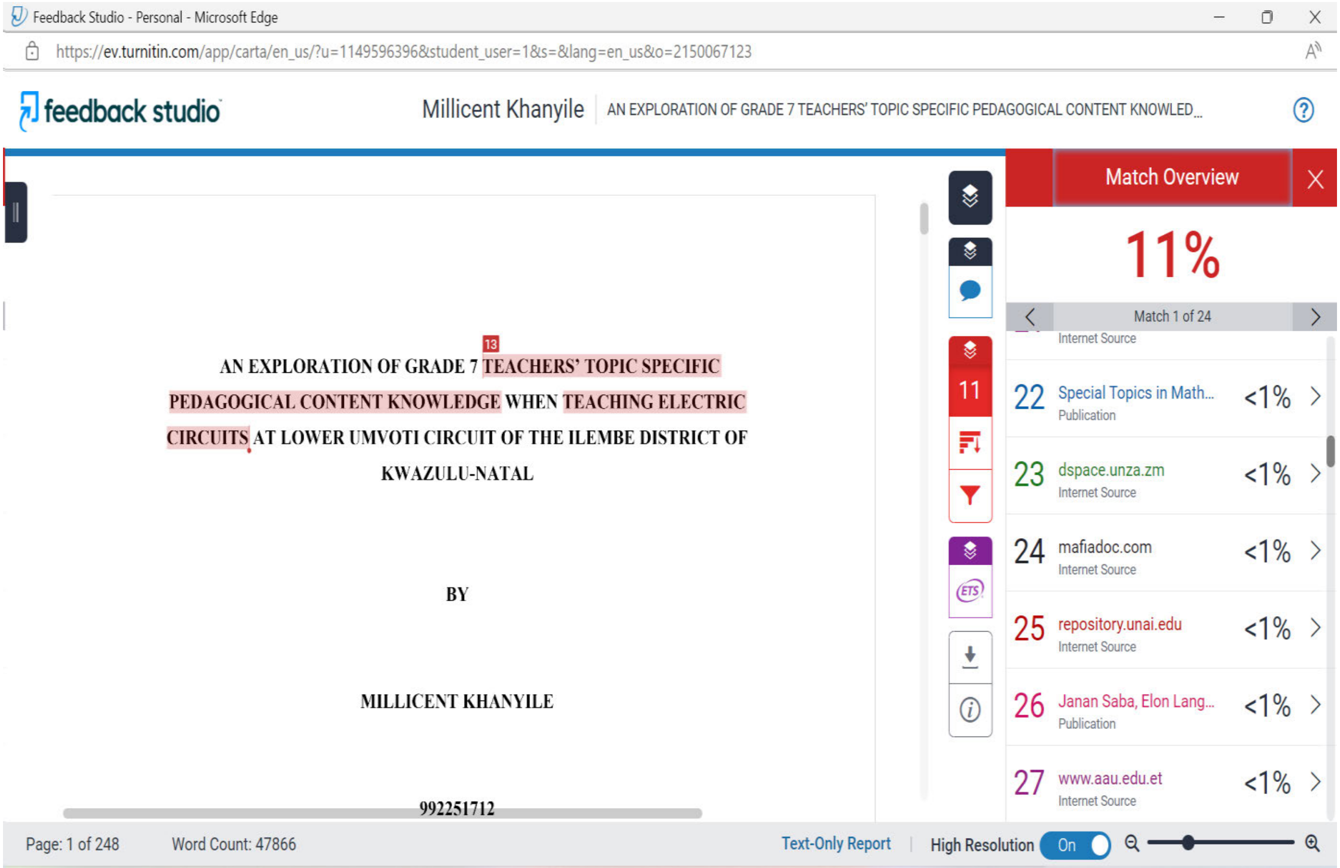
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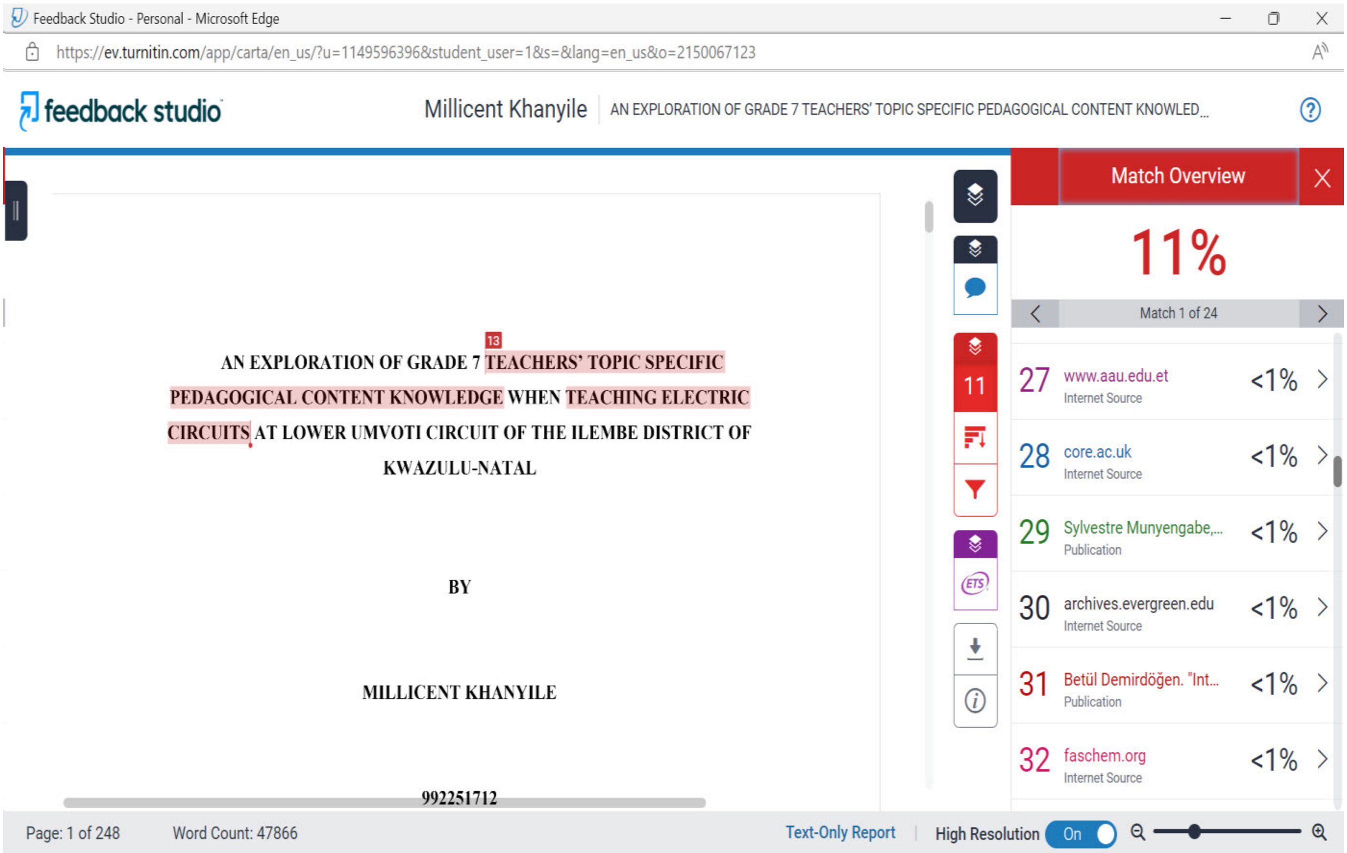
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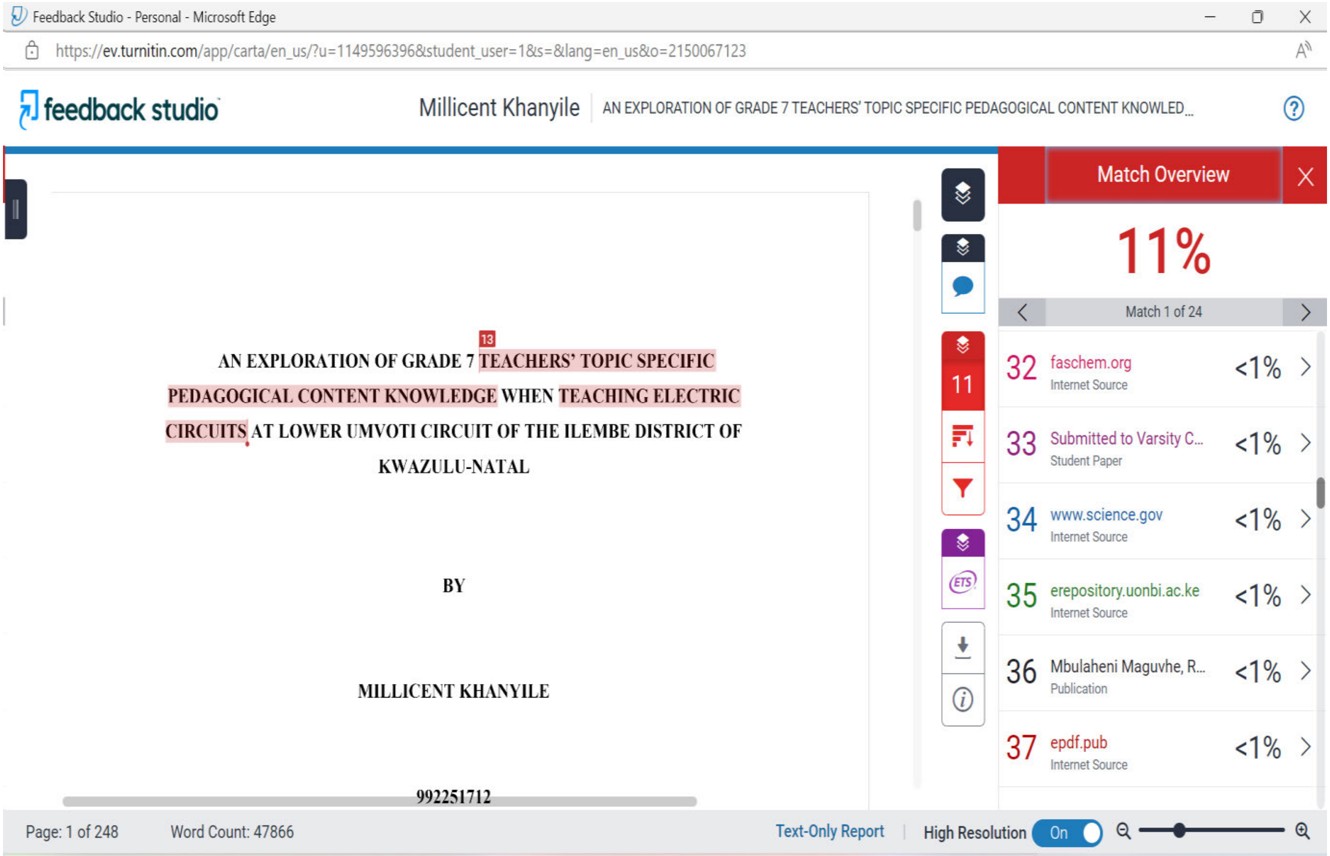

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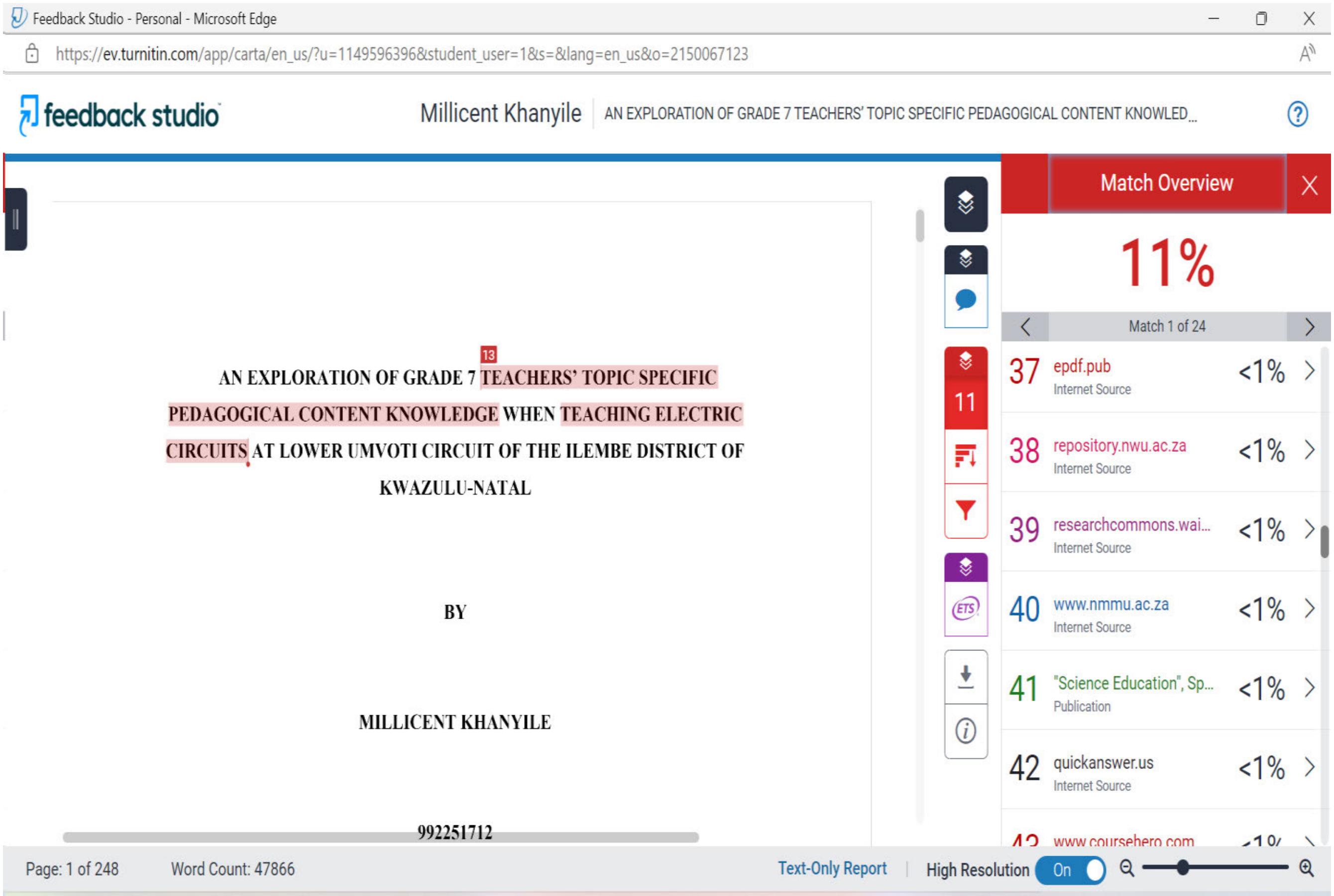

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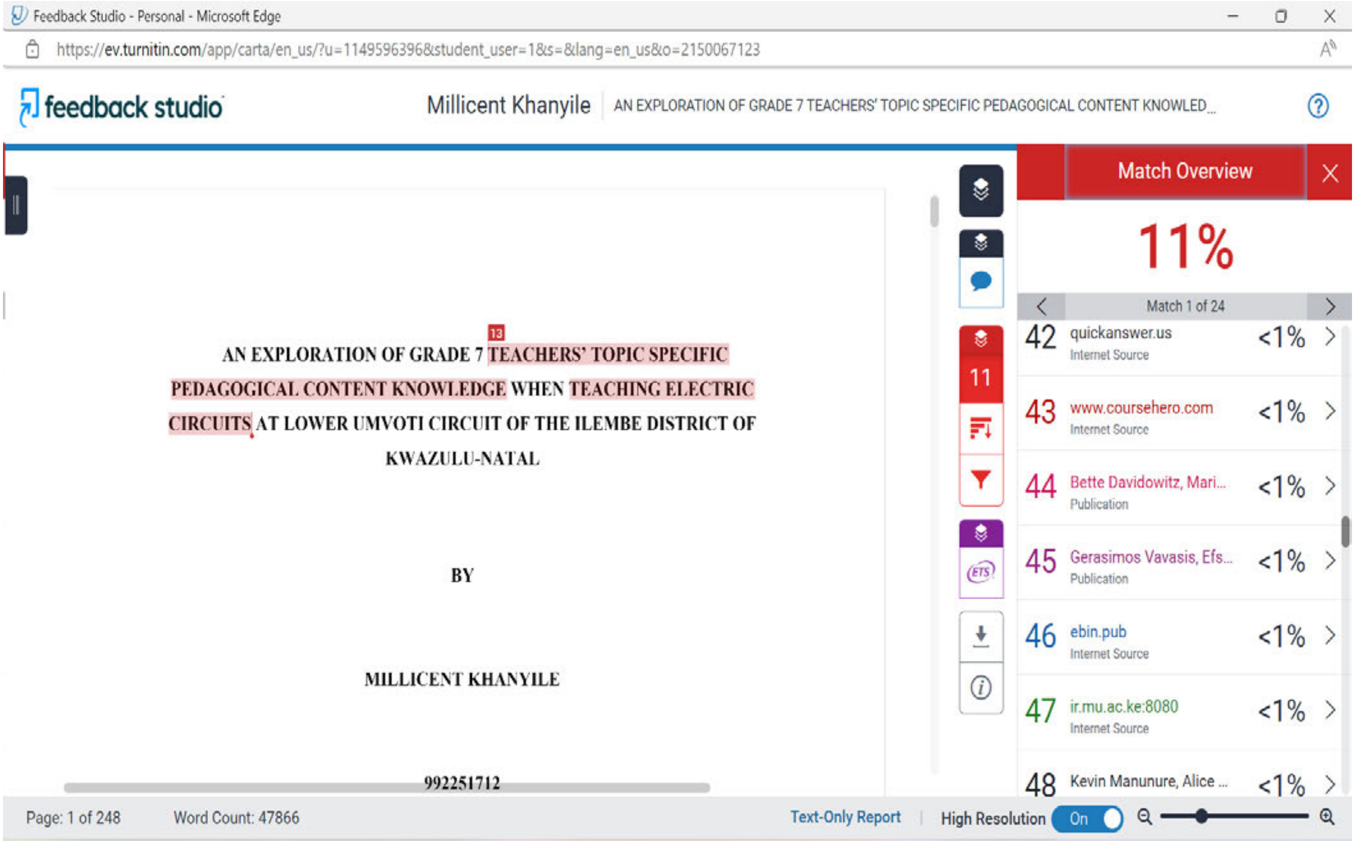
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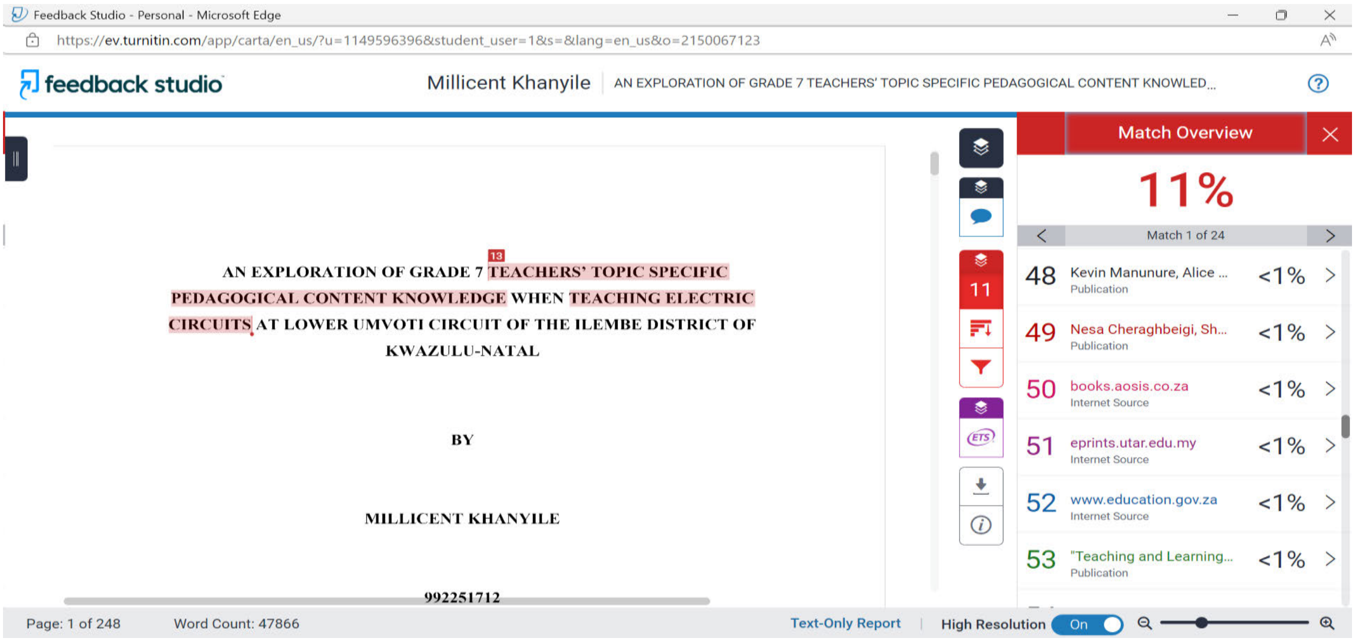
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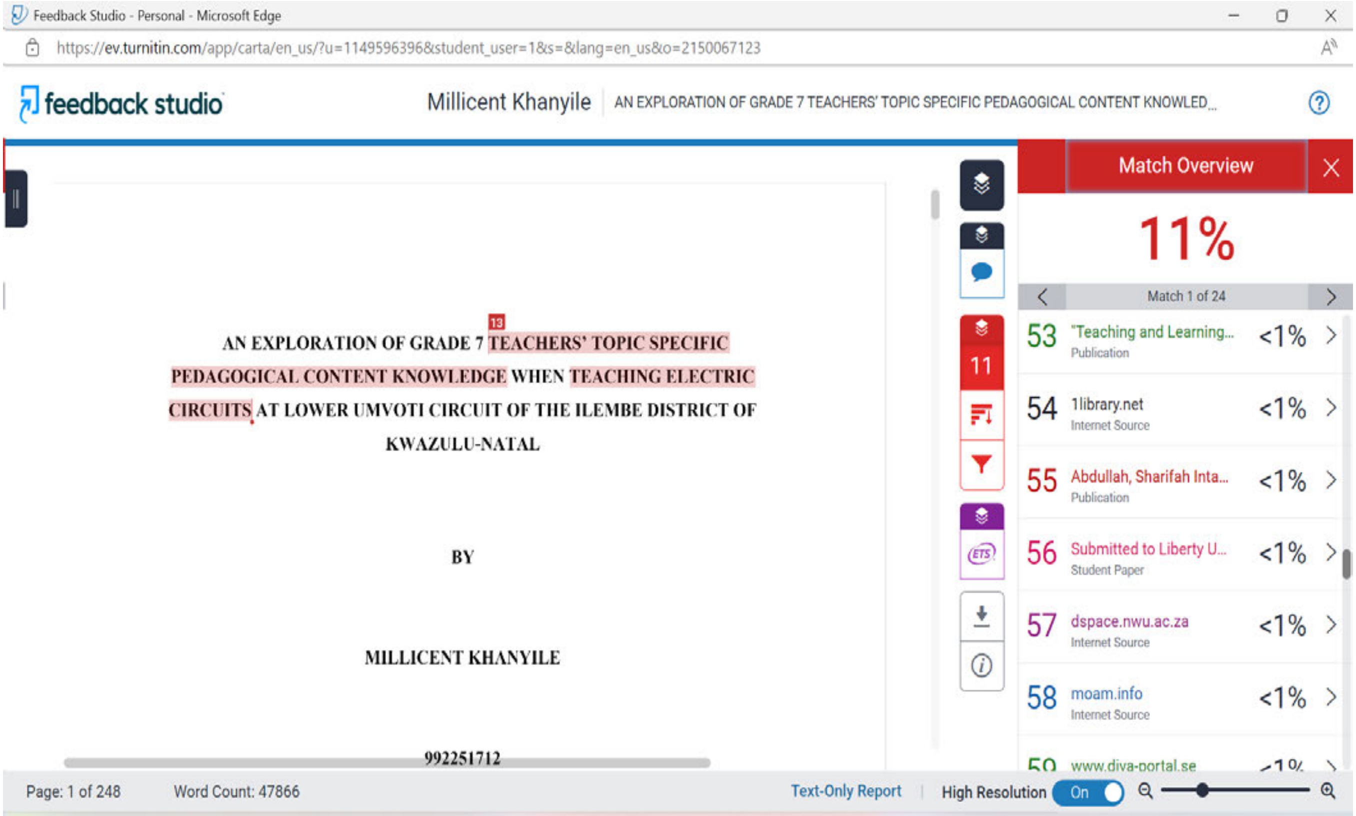
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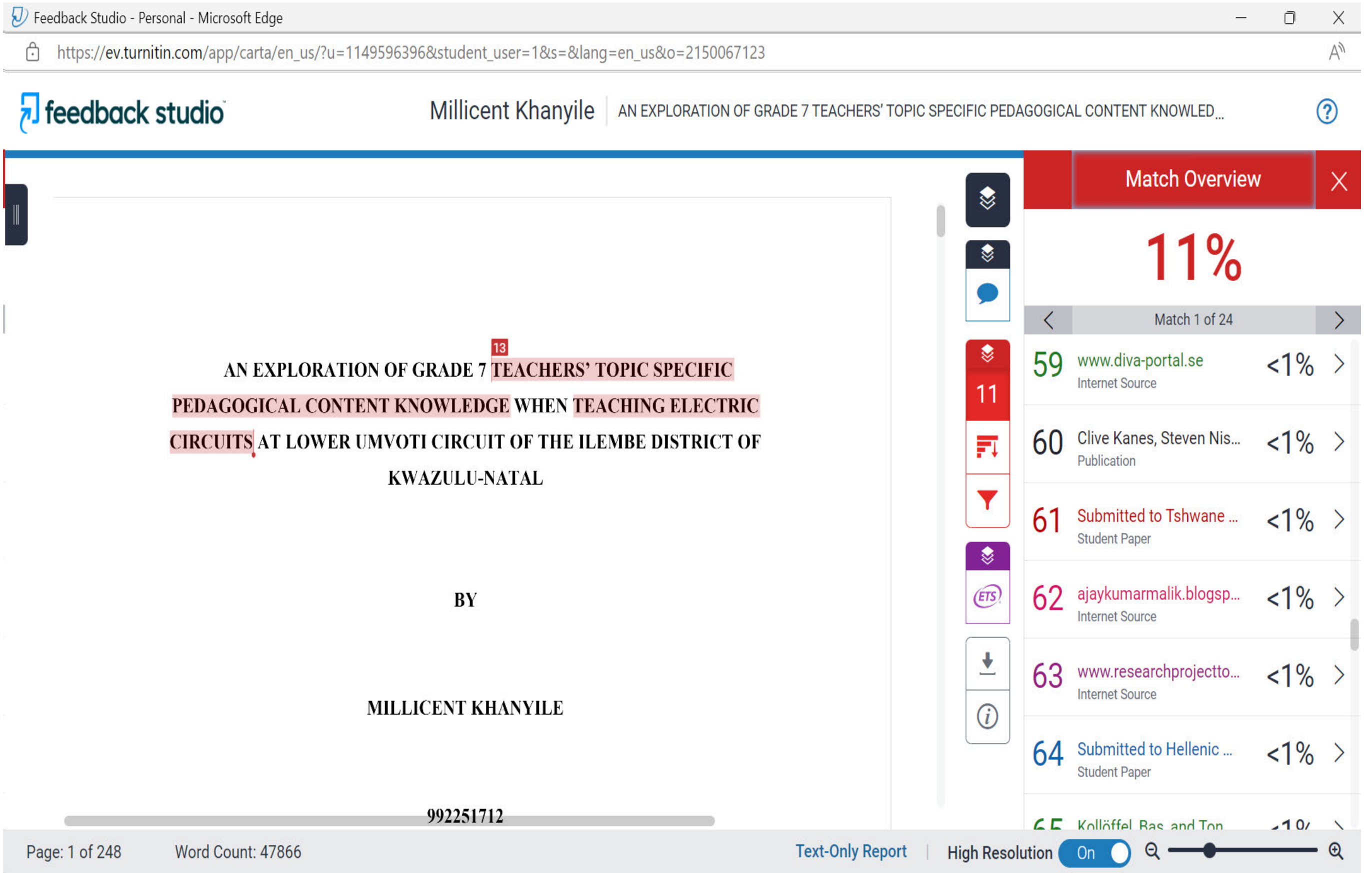
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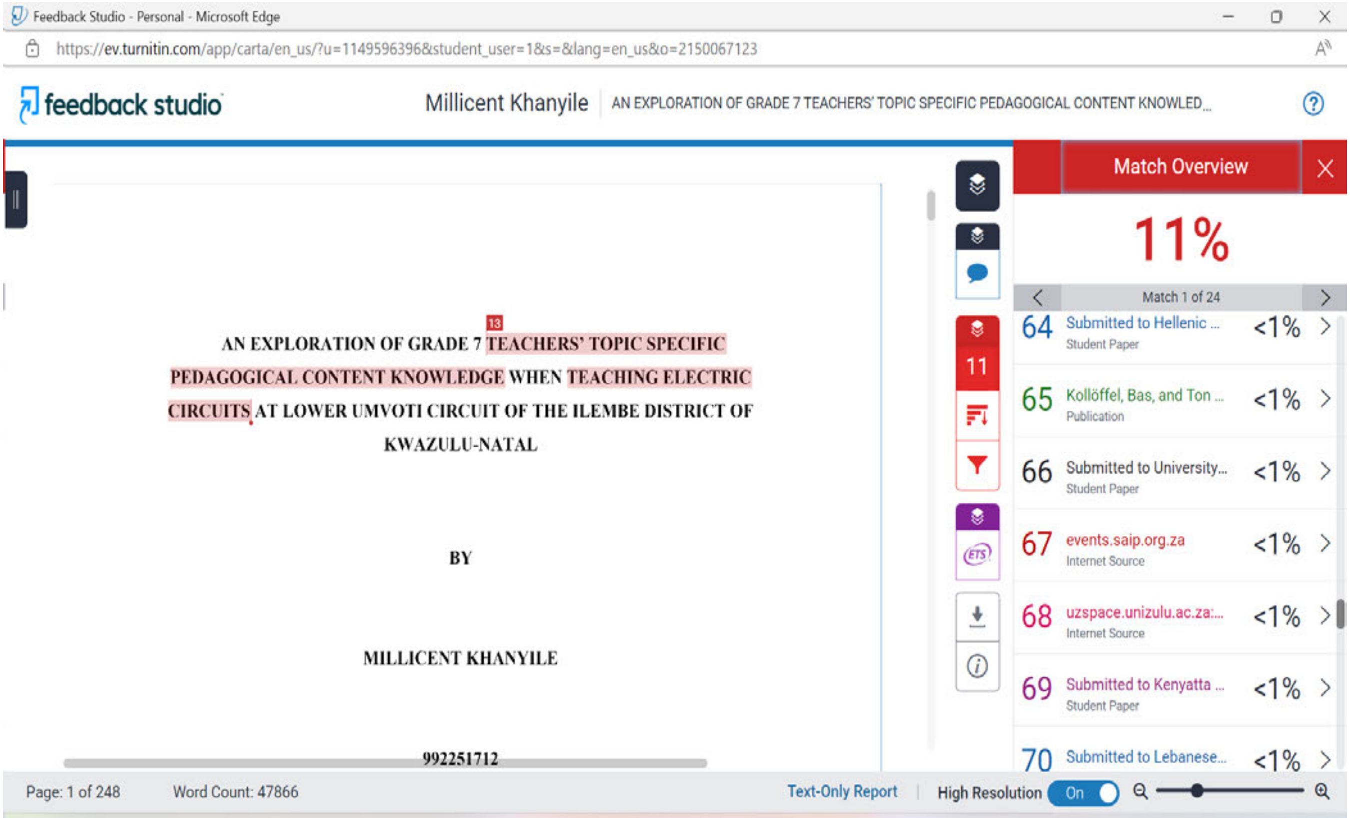
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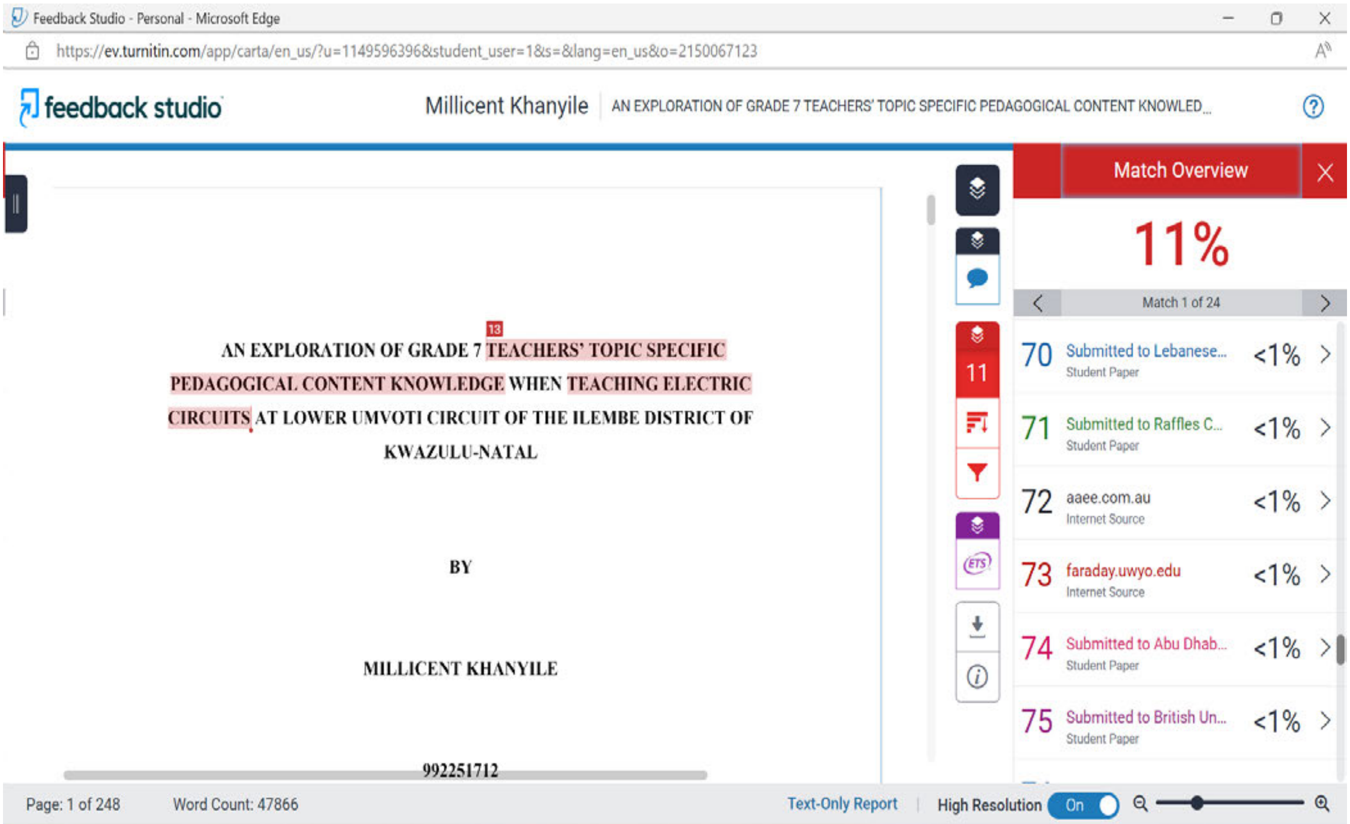
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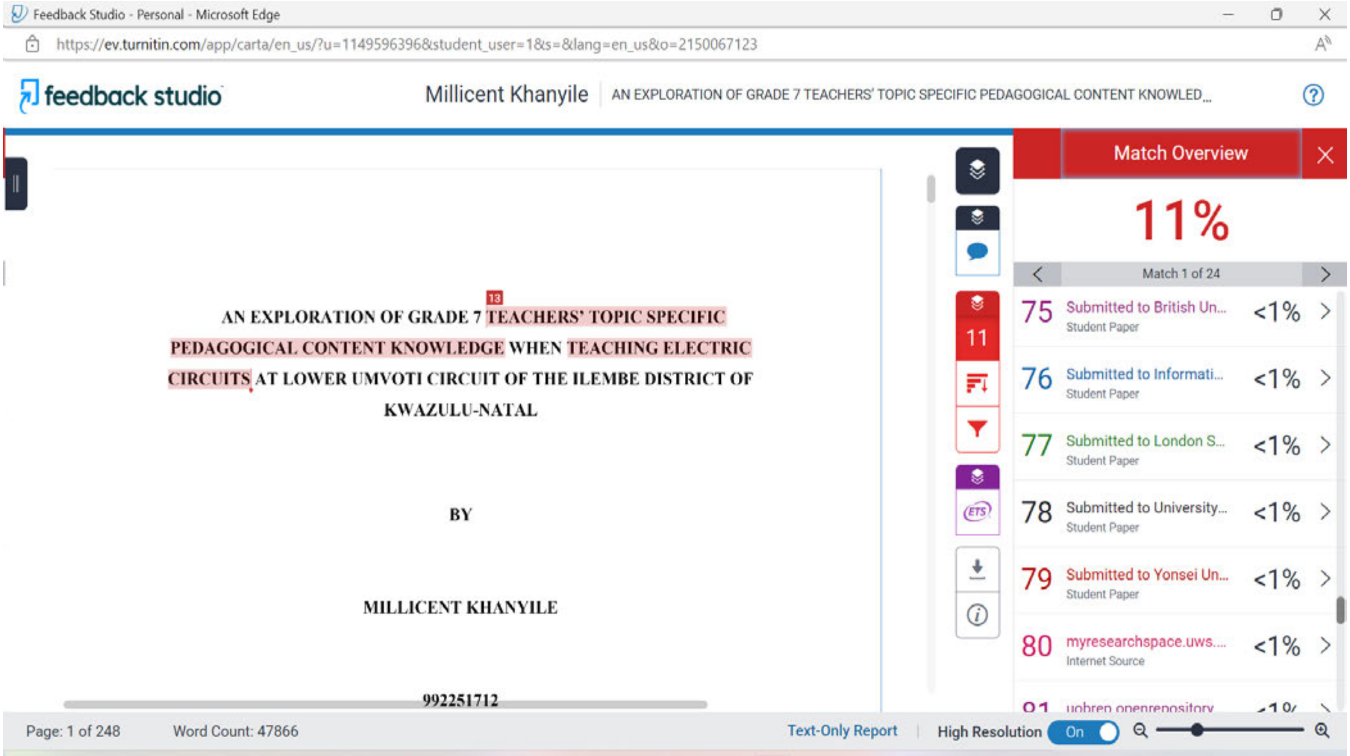
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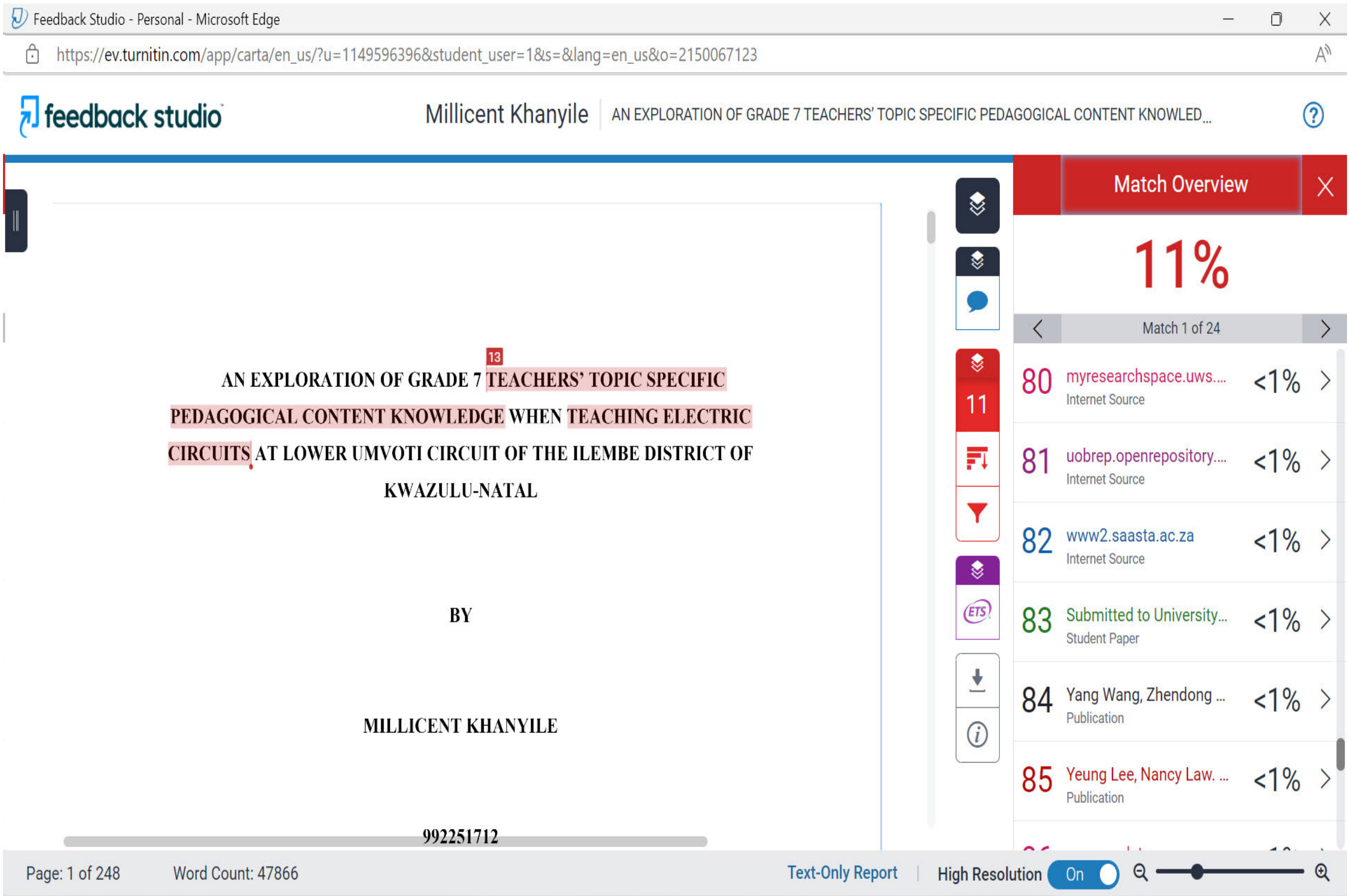
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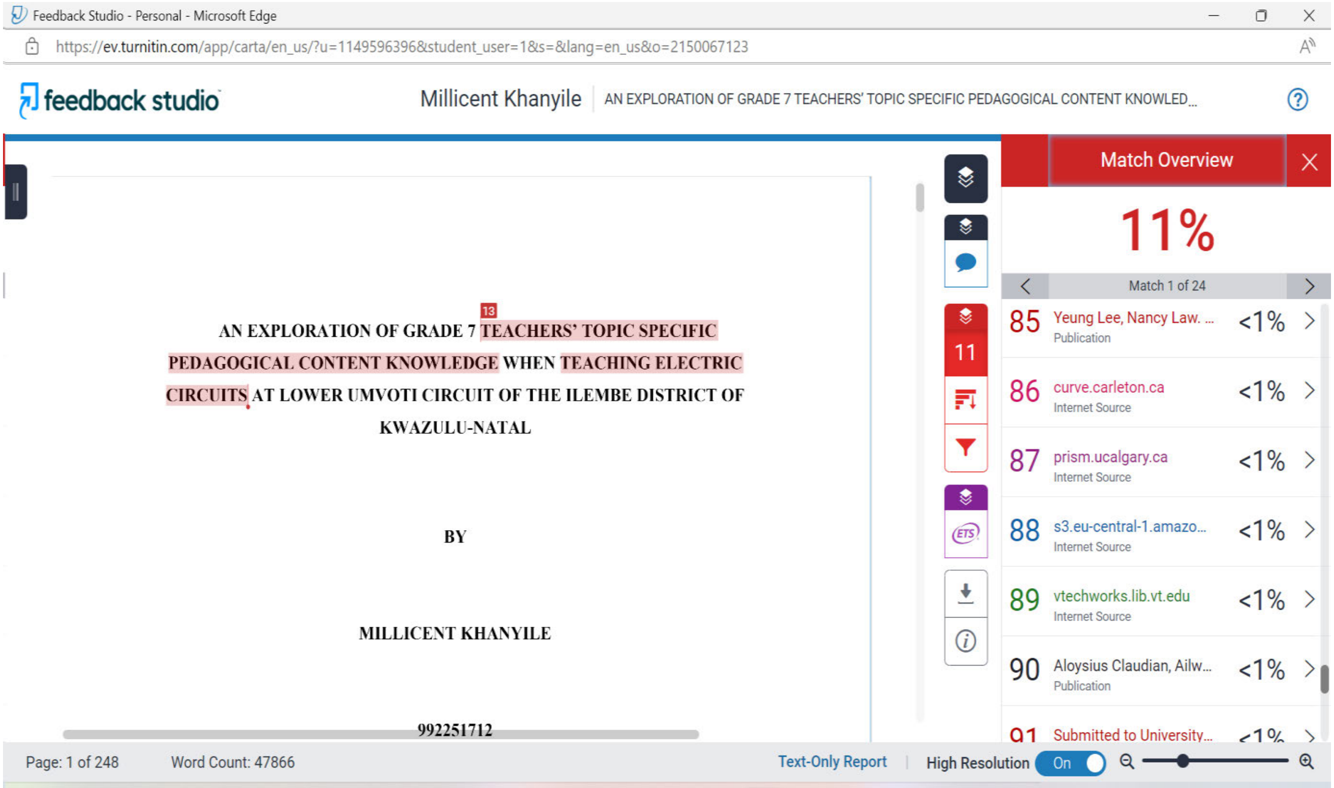
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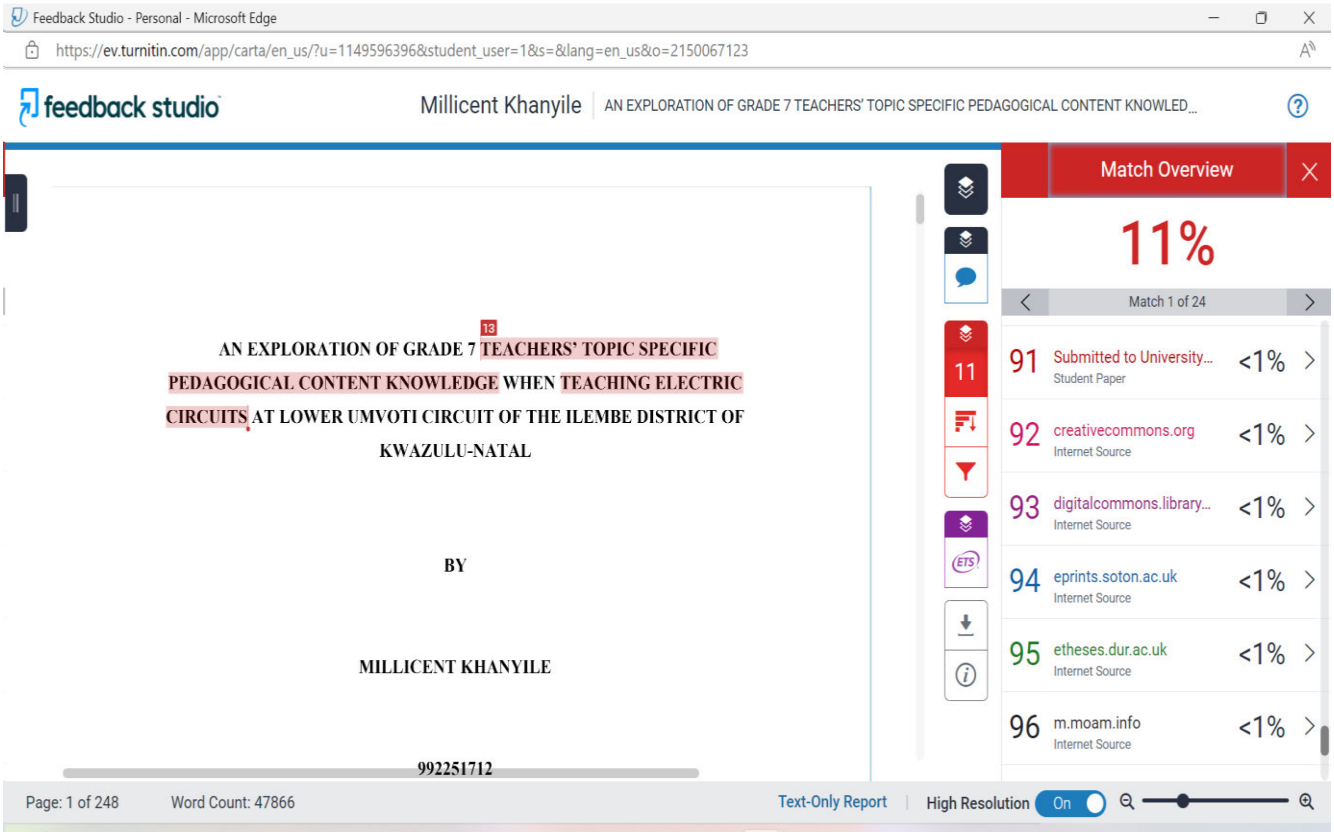
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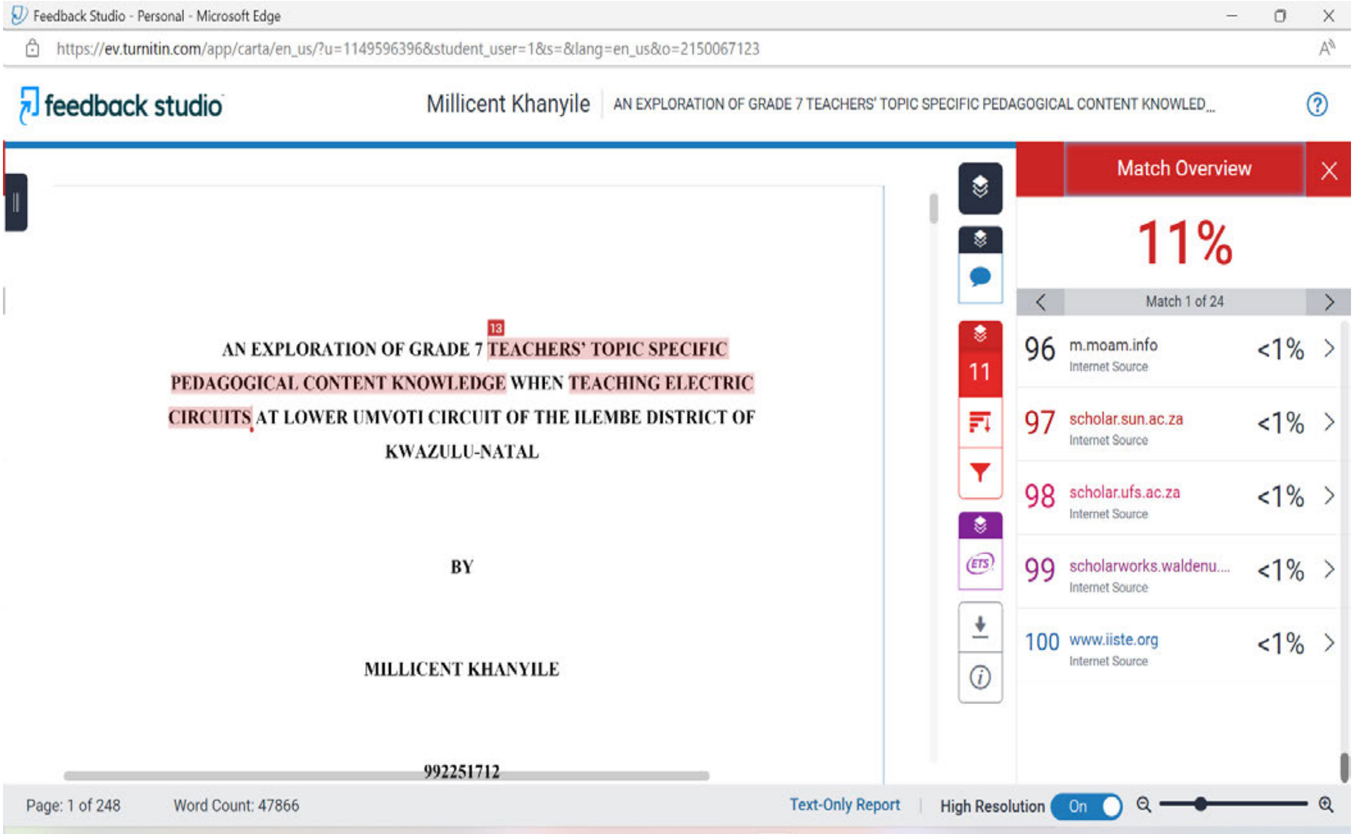
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