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# Affordances of textbooks for natural sciences teachers' enacted pedagogical content knowledge in electric circuits


**By**

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**Submitted in fulfilment of the requirements for the degree of Masters of Education (MEd)**

**In the Faculty of Education, University of Pretoria**


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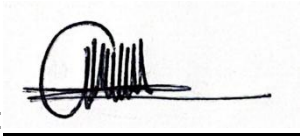
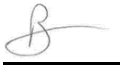
**June 2025**

## DECLARATION

I declare that the dissertation entitled, *Affordances of textbooks for natural sciences teachers' enacted pedagogical content knowledge in electric circuits*, which I hereby submit for the degree Master of Education at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Student: Crouse Ramapulana Maponya Signature: 

Supervisor: Dr Philip Mirkin Signature: 

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## DEDICATION

I dedicate this dissertation to my parents and siblings.

## ACKNOWLEDGMENT

First and foremost, I would like to thank God and acknowledge my ancestors. Also, I would like to thank God for the gift that he gave me, I shall make sure that I use it for good by inspiring others and making an impact in their professional lives.

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Last but not least, I would like to end the acknowledgments with a quote by Paulo Coelho:

*“When you want something, all the universe conspires in helping you to achieve it*”

With that being said, thank you to friends, peers, colleagues and everyone who call me “*Prof*” while being aware that I am not yet Prof But that is the end goal.

## ABSTRACT

This study investigated PCK revealed in natural sciences textbooks and its impact on teachers' enacted PCK when teaching electric circuits to Grade Nine learners. Four natural sciences teachers from public rural schools in Sekhukhune East District in Limpopo Province were conveniently and purposively sampled to participate in a qualitative case study, guided by an interpretive paradigm. Textbook data was collected from the three textbooks that the teachers used. Observations and interviews were used to gather data on teachers enacted PCK. The refined consensus model (RCM) of PCK was used as a conceptual framework to investigate collective PCK in textbooks and teachers enacted PCK. PCK was conceptualised using the components of knowledge related to: i) curricular saliency; ii) learners' understanding of science; and iii) conceptual teaching strategies including representations. Guided by the RCM and using PCK components, two rubrics were developed with a four-point scale to analyse the quality of textbooks and teachers' enacted PCK, respectively.

The findings indicate that the PCK revealed in natural sciences textbooks influenced teachers' enacted PCK, particularly in terms of the component of curricular saliency and conceptual teaching strategies, including representations. This influence can be attributed to the quality of PCK revealed in textbooks. It can be concluded that the textbook afforded teachers the opportunity to develop their enacted PCK and influenced their teaching of electric circuits. However, not all the teachers utilised the opportunities afforded by the textbooks. It is recommended that professional development programmes train teachers on the affordances and constraints of textbooks.

**Keywords:** enacted pedagogical content knowledge (ePCK), refined consensus model (RCM), textbook affordances, natural sciences teachers, electric circuits

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# CHAPTER 1: INTRODUCTION AND BACKGROUND OF THE STUDY

## 1.1 INTRODUCTION

This study examines the way in which textbooks influence science teachers' knowledge and practice when teaching electric circuits. In this chapter, I present the background that informed the study and the context in which the study took place. I then discuss the nature of textbooks as curriculum materials that are educative, pedagogical content knowledge (PCK) construct and the teaching of electric circuits. After that, I discuss the nature of science education in public rural schools in South Africa, and the location where this study took place. This is followed by discussing the problem statement, rationale, purpose and research questions. In conclusion, I present a summary of the research methodology and chapter overview.

## 1.2 CLARIFICATION OF CONCEPTS

This section provides clarification of how the following concepts were used in this study. The concepts are not listed in any order in any particular order.

- **Educative curriculum materials:** Curriculum materials that afford teachers learning. In this study, learners' textbooks are classified as educative curriculum materials.
- **PCK of a textbook:** The presentation of the collective PCK (cPCK) of the profession and affords the teachers the opportunity to transfer that cPCK to their personal PCK (pPCK) and develop it. In this study, the PCK of a textbook is referred to as "*PCK revealed in textbooks*".
- **Enacted PCK (ePCK):** Teachers' knowledge and skills revealed during lesson preparation, teaching and reflection after the lesson.

- **Electric circuits:** is a curriculum topic that is prescribed for Grade Nine learners under the subject of natural sciences. The fundamental concepts of electric circuits at this Grade are electric cells, resistance, and principles of simple electrical circuits (Department of Basic Education, 2011).

## 1.3 BACKGROUND OF THE STUDY

Textbooks are traditionally created for learners to gain the prescribed content knowledge and skills for a particular subject (Schneider et al., 2013). However, research shows that teachers use textbooks to prepare for lessons and present lessons in the classrooms (Horsley & Sikorová, 2015; Vojíř & Rusek, 2019). This implies that textbooks have the potential to afford teachers opportunities to develop their pedagogical content knowledge (PCK) (Bergqvist & Chang Rundgren, 2017). PCK refers to a teacher's professional knowledge base associated with transforming content knowledge in a way that learners can comprehend (Shulman, 1986). Since textbooks can develop teachers' PCK, they are considered educative curriculum materials. Davis and Krajcik (2005) define educative curriculum materials as those that are used to support teachers learning. In agreement with Davis and Krajcik (2005), well-developed educative curriculum materials contribute towards developing teachers' PCK, where a textbook ought to reveal exemplary PCK to develop teachers' PCK in a particular topic. This means that textbooks as educative curriculum materials ought to support teachers in anticipating learners thinking, misconceptions and ideas about the sciences and provide instructional representations that can be used to address the learners' misconceptions in order for effective teaching to take place (Davis & Krajcik, 2005).

PCK has been accepted as a theoretical construct for effective teaching. However, researchers in science education have conceptualised PCK differently, using knowledge components. The three most commonly used knowledge components are knowledge of learners' understanding of science concepts, representations and instructional strategies (Chan & Hume, 2019). These knowledge components are those proposed by Shulman (1986) in the original conception of PCK. Some researchers included PCK components of knowledge of pedagogy, curriculum, context, assessment, and orientation towards teaching science to conceptualise PCK (Chan & Hume, 2019). Considering that PCK can be conceptualised in different ways, PCK researchers ought to make it clear how they conceptualise the construct in their studies. In this study, PCK was conceptualised using PCK components proposed by experts of PCK in science education. These three components are: knowledge of curricular saliency; knowledge of learners' challenges; and misconceptions of science concepts as well as knowledge of representations used to present content in conceptual teaching strategies (Chan et al., 2019). In the next chapter, I discuss the three components in detail in section 2.2.2 of the literature review when discussing the theoretical framework. It is through these components that I investigated the PCK revealed in textbooks and the level at which teachers enact their own PCK.

Some researchers report that PCK exists at the topic level and term it topic-specific PCK (Mavhunga & Rollnick, 2013; Veal & MaKinster, 1999). This means that the knowledge needed to teach the topic of electric circuits will be different from that needed to teach the topic of electrodynamics. From my own experience, I have noted that textbooks present topics in different ways, even if the topics are from the same discipline, such as physics. On the other hand, teachers can also have adequate PCK about a given topic, but limited PCK about another topic. Consequently, this study

investigated PCK at the topic level, using the topic of electric circuits under the subject of Natural Sciences at the Grade Nine level. According to the Curriculum and Statement Policy Statement (CAPS), Natural Science in South Africa is made up of knowledge areas of life and living (biology), matters and materials (chemistry), energy and change (physics) and plant earth and beyond (astronomy and geology) (Department of Basic Education, 2011). The topic of electric circuits is taught under the knowledge area of energy and change. In this topic, learners learn about the fundamental concepts of voltage, current and resistance and the principles of series and parallel circuits. It is essential that learners develop a conceptual understanding of these concepts in Grade Nine as it lays the foundation for Physical Sciences which is taught from grades 10 – 12. Instructional resources such as textbooks can support the teacher in teaching the topic effectively in such a way that enhances the conceptual development of the fundamental concepts.

## 1.4 CONTEXT OF THE STUDY

This research took place in four secondary public non-fee-paying schools, situated in Sekhukhune East district in Limpopo Province in South Africa. The four schools are in rural areas in relation to which the closest town, Burgersfort, is located approximately 60 km away. Research shows that rural area schools face numerous challenges that negatively impact the teaching of science such as a lack of facilities including laboratories, a lack of resources for teaching and learning including textbooks, and overcrowded classrooms (Ndjangala et al., 2021; Netshivhumbe & Mudau, 2021). These four schools are no exception to these challenges. None have laboratories and all lack textbooks, where instead, learners share textbooks. The District suggests that the schools that do not have laboratories travel to another area in the same district to conduct practicals and experiments. However, because of challenges like budget

constraints, this is not always possible. One of the schools is large, with over a thousand learners and faces the challenges of overcrowding. Therefore, it might be difficult for teachers to give learners constructive feedback in this school. Three schools are small schools where the teachers teach two or more subjects from Grade 8 to 12 apart from Grade Nine Natural Sciences. This leads to teachers having a heavy teaching load and time stress having to prepare for many different classes (Ngema, 2016). Often times, the teachers in these small schools may end up relying on textbooks as instructional resources due to an excessive workload.

The other challenges faced by rural area schools are specific to teachers. Research shows that science teachers in rural areas often lack content knowledge and PCK (Ngema, 2016; Ntuli & Mudau, 2023). It cannot be generalised that this will be the case with science teachers in Sekhukhune East. The District provides content workshops for Natural Sciences and Physical Sciences teachers. Since some teachers teach both subjects, they attend both workshops. In a casual conversation with the Natural Science curriculum advisor, he stated that the poor academic performance in Natural Sciences in this District may be teachers' lack of content knowledge. He further speculated that this may be due to factors such as curriculum changes, or teachers not being comfortable teaching certain topics. At Physical Sciences workshops, the curriculum advisor pointed out that, when she gives teachers content knowledge tests, they score high marks, but when teaching learners the same content, this seems to be a challenge. The concept of a curriculum advisor supports the findings by Davidowitz and Potgieter (2016) that proficiency in content knowledge does not necessarily lead to exemplary PCK. It is for this reason that the District content workshop's primary purpose is to support teachers regarding how to teach the content to learners. In addition to workshops, teachers can use instructional resources such

as textbooks to develop their PCK. This approach is supported by Orgoványi-Gajdos (2015), who revealed that teachers rely on textbooks when they lack content knowledge and PCK.

## 1.5 PROBLEM STATEMENT

As discussed above, this study was based on rural area public schools in one of the districts in Limpopo Province. According to the Trends in International Mathematics and Science Study (TIMSS) 2019 report, the academic performance of Natural Science learners in Limpopo proves unsatisfactory (Department of Basic Education, 2019). The TIMSS report further reveals that poor performance in Natural Science is seen in schools located in rural areas more than in schools that are located in cities and suburbs. Regarding learners' knowledge and competence in science, the TIMSS report revealed that South African Grade Nine learners acquired 36% of basic science knowledge and only 15% who acquired this basic science knowledge were able to apply it (Department of Basic Education, 2019). This implies that most Natural Sciences learners in South Africa lack basic science knowledge and conceptual understanding of science concepts. Reddy et al. (2012) reported that poor performance in science is also observed from grade 10 to 12 under subjects like Physical Sciences. A diagnostic report of the National Senior Certificate (NSC) Physical Sciences results reveals that learners consistently face challenges and misconceptions regarding electric circuit concepts (Department of Basic Education, 2021, 2022, 2023). The diagnostic report of 2022 describes one of the common difficulties and misconceptions as follows:

> “Most candidates had difficulty interpreting the circuit. Candidates could not correctly identify the resistors that are in series and those in parallel. Many

> candidates thought the 2 Ω resistor was in series in the circuit. This has been a serious misconception for many years. Candidates seemed to think that parallel resistors must be in lines that are parallel to each other" (p. 230)

This difficulty and misconception have been reported in diagnostic reports for at least the past ten years, including 2023. The basic principles of simple electric circuits are taught in Grades Eight and Nine. This implies that Grade 12 learners struggle with basic electric circuit concepts, even though they started learning about the topic from lower grades. Furthermore, research also shows that learners have difficulties and misconceptions about electric circuits (Mbonyiryivuze et al., 2019).

Learners' outcomes, namely academic performance and understanding of science concepts are related to teachers' PCK (Akinyemi & Mavhunga, 2021). Mazibe et al. (2024) studied learners' academic performance of electrostatics in relation to teachers' PCK in South African classrooms. These authors reported that, although various factors influence learners' outcomes, the outcomes of learners' written tests of electrostatics matched teachers' PCK. Since it is commonly accepted that learners' outcomes are related to teachers' PCK, teachers should reveal exemplary PCK to help learners understand abstract topics like electric circuits. Studies in South Africa indicate that, even though in-service teachers have adequate content knowledge, their topic-specific PCK in electric circuits is poor (Gaigher, 2014; Moodley & Gaigher, 2019; Poti et al., 2022). Therefore, it is necessary to improve in-service teachers' PCK. Professional development programmes are one of the strategies by the South African Department of Education to improve teachers' PCK. However, there are contradictory findings on whether or not these programmes improve teachers' PCK. Pitjeng-

Mosabala and Rollnick (2018) reported that in-service teachers' PCK improved after a professional development programme. On the other hand, Poti et al. (2022) reported that in-service teachers' PCK did not necessarily improve after a professional development programme. Researchers need to investigate other ways in which in-service teachers are able to improve their PCK. For this reason, this study focuses on how textbooks as educative curriculum materials influences and support in-service teachers enacted PCK.

## 1.6 RATIONALE OF THE STUDY

As indicated in the background of this research, teachers use textbooks as educative curriculum materials to plan and present lessons. Even though teachers might be using other curriculum materials such as workbooks and computer software, textbooks remain the primary resource for teaching and learning in most classrooms (Horsley & Sikorová, 2015), as was the case in the schools used in this research. Since textbooks are primary resources teachers use, this study focused on the impact of textbooks on teachers' enacted PCK. Before one can examine the way in which textbooks influence teachers' PCK, there needs to be an analysis of textbooks with reference to PCK to investigate if the textbooks afford teachers opportunities to develop their PCK. There is a paucity of literature on the analysis of textbooks regarding the construct of PCK (Mazibe & Rollnick, 2023).

Researchers analysed PCK components in textbooks separately by focusing on either learners' understanding of science concepts, or instructional representations or curricular saliency (Vojíř & Rusek, 2019). This research will contribute to existing knowledge about the analysis of textbooks with reference to PCK, using the knowledge of curricular saliency, learners' challenges and misconceptions of science

concepts, and representations used to present the content in conceptual teaching strategies. Furthermore, the study will provide empirical evidence of whether the way the in which the components of PCK are presented in textbooks contains educative features that can support teacher learning for in-service teachers in rural areas. The findings will provide insights into the PCK revealed in textbooks which will highlight the strong points of textbooks and limitations. This can be useful to teacher education institutions when training teachers on how to use curriculum materials, department of education when revising criteria of approving textbooks and textbook authors when designing textbooks both for the learners and teachers.

The relationship between the use of textbooks and teachers' PCK and practice is not an obvious one. One cannot conclude that textbooks have no impact on teachers' PCK nor that textbooks do not have an impact on teachers' PCK in a way that they develop teachers' PCK. Saeli et al. (2012) reported a weak correlation between PCK revealed in textbooks and teachers' PCK. The weak correlation can be attributed to the instruments used to measure teachers' PCK. The researchers (Saeli et al., 2012) used questionnaires to capture teachers PCK. As reported by Alonzo and Kim (2016), PCK captured in written formats does not necessarily translate into teachers' practice in the classroom. As such, it is necessary to focus on both PCK and practice when researching the way in which textbooks influence teachers' PCK and practice. Mili and Winch (2019) reported a strong relationship between PCK revealed in textbooks and teachers' PCK and practice. In their (Mili & Winch, 2019) study, teachers with adequate content knowledge and PCK used textbooks effectively in order to explain concepts to learners while teachers who lacked content knowledge and PCK used textbooks inadequately. These are interesting findings given that textbooks are perceived to be a primary resource for novice teachers who lack content knowledge and PCK. As

such, I concur with the notion that textbooks can be a powerful pedagogical tool that develops teachers' PCK and practice. This study will report on how science teachers' use of textbooks influences their PCK and practice when teaching a challenging topic of electric circuits.

Apart from the academic rationale provided above, I conducted this study to determine how fellow teachers use textbooks when they teach physics topics. My interest in researching textbooks derives from my honours research project analysing textbooks through the lens of PCK. The research caused me to reflect on my use of textbooks for teaching science. I realised that textbooks are limited in the way in which they provide static pictures, but remain useful to teach, especially in rural schools, where it is the only source of information for learners. The models, diagrams, and analogies in textbooks are useful to explain concepts such as voltage and current in electric circuits. However, a teacher ought to make learners aware of the limitations of the instructional representations from the textbooks, as this can reinforce misconceptions, which was not the intention of the teacher or textbook author. This implies that textbooks ought to be used with caution, as learners can interpret them as they see fit. I observed that even though learners have the textbooks, they still struggle to understand the content presented in textbooks. This is where a teacher plays an essential role, by making the content in the textbook accessible to learners, and going beyond the textbook in order for learners to understand the content better.

## 1.7 PURPOSE OF THE STUDY

The main aim of this research was to examine the impact of PCK revealed in Natural Sciences textbooks on science teachers' PCK and practice when teaching electric

circuits at Sekhukhune East District in public non-fee paying schools. To achieve this goal, I formulated the following objectives:

- The first objective was to conduct an in-depth content analysis of the PCK revealed in the Natural Sciences textbooks about electric circuits at the Grade Nine level used by teachers in this study.
- The second objective was to investigate how the PCK revealed in Natural Sciences textbooks impacts teachers' enacted PCK about electric circuits when planning and teaching electric circuits.

The first objective was to investigate opportunities that Natural Sciences textbooks afford teachers to develop their PCK in electric circuits. As such, the textbooks were analysed through the lens of PCK to reveal their quality in terms of PCK components of knowledge of curricular saliency, knowledge of learners' challenges and misconceptions of science concepts, and knowledge of representations used to present the content in conceptual teaching strategies. This study was conducted under the assumption that if textbooks reveal developing or exemplary PCK in these components, then the textbooks are educative and afford teachers opportunities to develop their PCK which shapes their practice. The second objective was to investigate the way in which teachers utilise the opportunities afforded by textbooks to present content to learners. I acknowledge that teachers' PCK is influenced by other factors than textbooks, but in this study, the focus was only on textbooks. The goal was to investigate how PCK revealed in textbooks becomes part of the teachers' enacted PCK.

## 1.8 RESEARCH QUESTIONS

**Primary research question:**

- How does the PCK revealed in Natural Sciences textbooks influence in-service teachers' PCK and practice in the curriculum topic of electric circuits?

**Secondary research questions**

- How do the Natural Sciences textbooks present the prescribed content of electric circuits regarding selected PCK components?
- How does the PCK revealed in Natural Sciences textbooks impact in-service teachers' PCK when preparing to teach electric circuits?
- How does the PCK revealed in Natural Sciences textbooks impact in-service teachers' enacted PCK when teaching electric circuits to Grade Nine learners in the classroom?

## 1.9 RESEARCH DESIGN AND METHODOLOGY

A qualitative research method from an interpretative perspective was adopted to investigate the influence of textbooks of PCK presented in the textbook, and how the way in which the content is presented develops teacher PCK. Given that textbooks and teachers do not present content knowledge the same way, a case study was used as a research design. Four science teachers and three textbooks were sampled using a purposive sampling strategy. The teachers were sampled on the basis that they use textbooks as curriculum materials when preparing and teaching electric circuits. On the other hand, the three textbooks were sampled on the basis that they are used by the participating teachers. Content analysis was used to investigate the opportunities afforded by the textbooks where PCK components served as pre-determined themes

to analysis PCK presented in textbooks. For teachers, data was collected from classroom observations which was followed by interviews after the teacher completed teaching the topic. Two PCK rubrics were developed and used to analyse the data collected from textbooks and teachers respectively. Chapter Three presents the full methodology of the study.

## 1.10 CHAPTERS OVERVIEW

This study is divided into six chapters. Chapter One introduces the reader to the study by providing the context under which the study took place and the background that informed the research. The problem statement and rationale of the study are outlined, followed by the aim, objectives, and research questions.

Chapter Two presents the literature review, which is divided into three sections. The first section is concerns PCK literature, where I discuss the conceptualisation, recent frameworks of PCK, development of teachers' PCK and how PCK has been captured and measured in science education. The second section reviews the literature on textbook analysis and the influence of textbooks on teachers' knowledge. The last section concerns the challenges and misconceptions in electric circuits, and how the topic can best be taught to develop conceptual reasoning and critical thinking.

Chapter Three presents the methodology of this study, where I discuss the research paradigm, method, and design. I also discuss how data was collected and analysed. Lastly, I discuss how I ensured that the findings were credible and trustworthy and the ethics that were considered.

Chapter Four presents the content analysis of three textbooks. There is a brief description of each textbook, after which the textbooks are presented separately as

case studies. In conclusion, I present an overview of the quality of PCK in textbooks in a table form and brief discussion.

Chapter Five presents the content analysis of teachers PCK and practice in relation to the PCK revealed in the textbooks that they used. The four teachers are presented one at a time with PCK components as themes. I then discuss how teachers used the textbooks during planning and teaching in the classroom.

Chapter Six presents the discussion and conclusion of the results. I address the research questions, discuss the limitations of the research, present the emerging findings, and make recommendations for further research based on these findings.

## 1.11 CONCLUSION

In this chapter, I presented the background and context of this study. I started by clarifying concepts that are used in this study. In those concepts, it was important to clarify the concept of “PCK of the textbook”, because PCK is usually associated with teachers, and not textbooks. For the background section, textbooks were discussed as educative curriculum materials, provided that they reveal exemplary PCK. For the context, I discussed challenges that are faced by rural areas schools, and the role of textbooks in those challenges. Thereafter, a discussion took place of the problem statement, rationale, purpose of the study and research questions. Lastly, I presented a brief description of the research methodology and chapter overview. In the next chapter, I review the literature relevant to this study guided by the purpose, objectives and research questions of this study.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter presents the literature applicable to this study in three sections. Firstly, I present the PCK construct where I discuss how PCK is conceptualised, along with the refined consensus model (RCM) of PCK. The model was adopted as a conceptual framework that guided this study. Furthermore, I discuss how teachers' PCK develops with reference to RCM, and how PCK is both captured and assessed. Secondly, I review the literature on textbooks as educative curriculum materials, discussing textbook analysis using the selected PCK components and the influence of textbooks on teaching science concepts. Lastly, I address learning of electric circuits, focusing on learners' difficulties and misconceptions of fundamental concepts of the topic and the teaching of the topic, focussing on the suggested instructional strategies to address these challenges.

## 2.2 PEDAGOGICAL CONTENT KNOWLEDGE (PCK)

PCK has been embraced as a valuable construct to examine teachers' knowledge of teaching and practice in science education (Chan & Hume, 2019; Kind, 2009). According to Shulman (1987),

"PCK *represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented and adapted to the diverse interests and abilities of learners, and presented for instruction*" (p. 8)

This implies that, before any teaching situation, the teacher has gained adequate content and pedagogical knowledge, because these are significant to classroom instruction. Research in science education supports Shulman's notion (Kind & Chan,

2019; Pitjeng-Mosabala & Rollnick, 2018), where Neumann et al. (2019) reported that the intersection of content knowledge and pedagogical knowledge constitutes a prerequisite for transforming the subject content knowledge into teachable forms. The transformation of content knowledge emerges through knowledge components of PCK. In his original conception, Shulman conceptualised PCK using the components of learners' challenges and misconceptions and component of instructional representations and strategies that address learners' challenges and misconceptions in order to enhance conceptual understanding (Shulman, 1986).

### 2.2.1 PCK conceptualisation

Over the years, researchers encountered challenges in establishing consensus on the conceptualisation of PCK. There have been disagreements about defining PCK, knowledge components, methodologies for investigation, data sources, and how teachers PCK develop. As a result, several models of PCK have been proposed to conceptualise PCK. Nevertheless, all the models used knowledge components to conceptualise PCK. Gess-Newsome (1999) distinguished the models into integrative and transformative, respectively. In the integrative model, PCK is not regarded as a separate knowledge base, rather that PCK is the integration of various knowledge bases such as content knowledge, contextual knowledge and pedagogical knowledge (Kind, 2009). On the other hand, the transformative model regards PCK as a separate knowledge base whereby content knowledge is transformed from other knowledge bases (Neumann et al., 2019). Researchers adopted either an integrative or transformative model to investigate teachers' PCK (Chan & Hume, 2019).

Magnusson et al. (1999) adopted the transformative perspective and designed a model for science teaching building on earlier models after Shulman’s model. Their

model is made up of the following knowledge components: orientation towards science teaching; knowledge and beliefs about science curriculum; knowledge and belief about learners understanding of science concepts; knowledge and beliefs about instructional strategies; knowledge and beliefs about assessment of scientific literacy (Magnusson et al., 1999). In the model, orientation towards science teaching shapes and in return it is shaped by the four components (Neumann et al., 2019). Extent literature shows that this model is commonly used in science education internationally (Chan & Hume, 2019; Mientus et al., 2022). The model (Magnusson et al., 1999) along with other models were used to investigate PCK at different grain sizes of PCK, whether subject-specific or discipline-specific. Mavhunga and Rollnick (2013) developed a topic-specific PCK (TSPCK) model to investigate PCK within a specific topic. In the TSPCK model, content knowledge of a particular topic emerges through content-specific knowledge components, namely: curricular saliency; learners' prior knowledge; what is difficult to teach; and representations including analogies and conceptual teaching strategies. Local studies on PCK used the model to investigate teachers' PCK in specific topics such as organic chemistry (Davidowitz & Potgieter, 2016), electrostatics (Mazibe et al., 2024) and the topic of this study, electric circuits (Mavhunga et al., 2016).

Based on the above discussion, it is evident that the models of PCK do not contradict one another, but rather, represent different conceptualisations of PCK, with some similarities and differences. To address the variations of PCK conceptualisation, PCK researchers in science education held a PCK summit in 2012 in Colorado to agree on a consensus model of PCK. Their model, known as teacher professional knowledge and skills (TPK&S) includes PCK (Gess-Newsome, 2015) (see Figure 2.1 below). The model begins with teacher professional knowledge bases (TPKB), which are generic

to the teaching profession, and which results from best practices and research in the outer layer of knowledge bases. TPKB categories in the model include knowledge related to content, pedagogy, students, curriculum, and assessment. TPKB shapes and is shaped by topic-specific professional knowledge (TSPK), the second layer of knowledge bases. TSPK is public knowledge that is held by the professionals in education and it is available for study or use by teachers (Gess-Newsome, 2015). Similar to TPKB, TSPK is canonical PCK, representing knowledge that is agreed upon by professionals and it is formed by research or collective wisdom of experts from best practices (Smith & Banilower, 2015). TSPK is PCK within a topic characterised by knowledge specific to a particular topic. As such, the knowledge components that underpin TSPK are specific to a topic. As shown in the model, the components used are knowledge related to instructional strategies, content representations, learners' understanding, science practices, and habits of the mind (Gess-Newsome, 2015). In this study, manifestations of TSPK is found in PCK revealed in natural sciences textbooks. Textbook knowledge represent knowledge from collective wisdom of authors from research and/ or best practice and this knowledge is available to use by teachers and for a study.

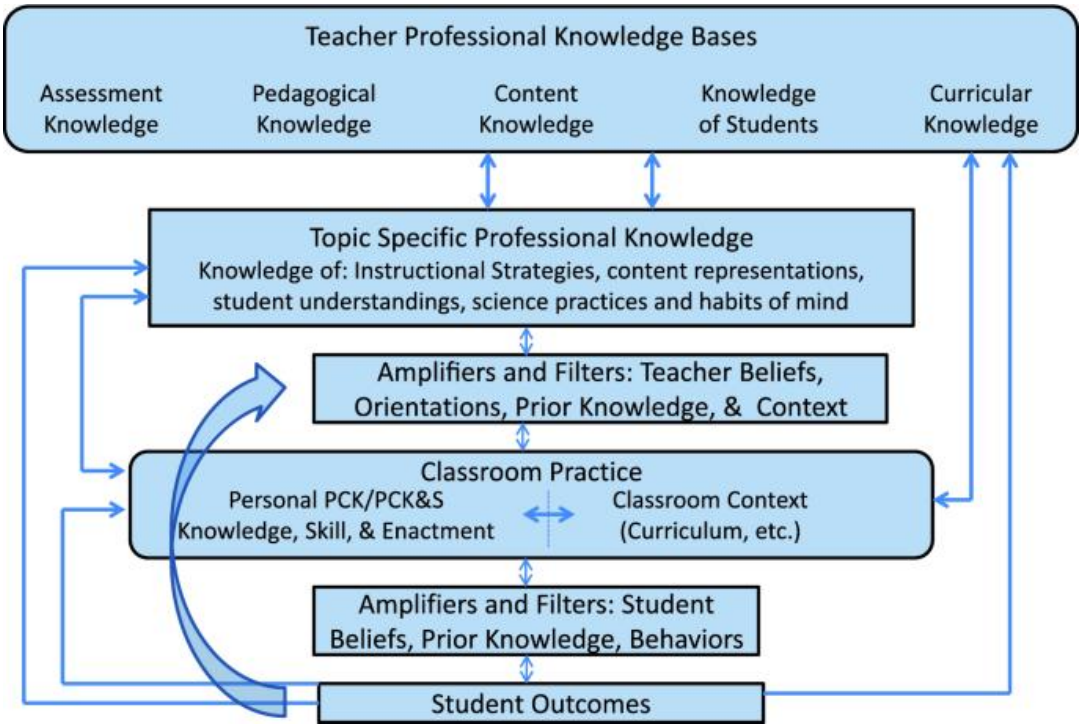



***Figure 2.1: Model of teacher professional knowledge and skills (TPK&S) including PCK (Gess-Newsome, 2015)***

Canonical PCK, in this case, TSPK informs classroom practice, where it becomes personal PCK through the application of planning a lesson, teaching in the classroom and reflecting on the lessons (Smith & Banilower, 2015). Personal PCK is located within an individual, and draws from PCK held in the profession. Teachers personalise TSPK through amplifiers and filters such as teachers' beliefs, context and orientations towards teaching science. Magnusson et al. (1999) included teachers' beliefs and orientations towards teaching science as a knowledge component but in the model of TSPK and Skills including PCK, these are regarded as amplifiers and filters that influence knowledge exchange between TSPK and teachers' personal PCK. For instance, if a textbook uses analogies, models and diagrams to represent concepts, and the teacher does not believe in using analogies, the teacher will filter out analogies and use the models and diagrams adapting them to suit their context of teaching.

Amplifiers and filters address the limitations that Shulman (2015) identified with his initial conceptualisation of PCK. The limitation is the absence of affect, emotions, teachers' goals of teaching and omission of context.

According to the model, PCK is located in classroom practice and it is termed personal PCK and personal PCK and skills. The key distinction between personal PCK and personal PCK and skills is that the first refers to teachers' knowledge (what the teachers know), while the second refers to teachers' knowledge and practice (what the teacher knows and does). Personal PCK meanwhile refers to knowledge of teaching found in instructional lesson plans and reasons that teachers give for their instructional practices. Gess-Newsome (2015) define personal PCK and skills as:

*"…the act of teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes" (p. 36)*

What is evident from the definition is that PCK includes practice and it is related to learners' outcomes. These are the other limitations that Shulman (2015) mentioned when reflecting on the initial conceptualisation of PCK. Overall, the model of Teacher Professional Knowledge and Skills (TPK&S) including PCK (as depicted in Figure 2.1 above) contributed to our understanding of how PCK can be conceptualised, taking into account previous models. The model clearly shows how PCK is related to other knowledge bases, distinguishes between PCK shared in the profession and individual PCK and addresses the limitations of the initial conceptualisation of PCK. However, the limitation of the model lies in its insufficient detail regarding PCK (Carlson et al., 2019). For instance, the distinction between TSPK and personal PCK&S concerning PCK is unclear. These limitations led to the development of the refined consensus model (RCM), which emerged from the PCK summit held in 2016, and attended by

PCK researchers from various continents. The RCM, which guided this study, is discussed in the following section.

### 2.2.2 Conceptual Framework

Mientus et al. (2022) showed that the refined consensus model (RCM) of PCK is a useful model for investigating PCK. They report that the RCM takes into consideration both the integrative and transformative perspectives of PCK. Consequently, the RCM of PCK as developed by Carlson et al. (2019) is used as the conceptual framework to guide this study. The RCM does not replace models discussed in the previous section, rather it presents an improvement of the consensus model in terms of making PCK explicit. The professional knowledge bases are the foundation to which PCK develops, just as for the consensus model. What is unique from the consensus model is that among the professional knowledge bases, content knowledge plays a huge role, as indicated in the outer layer of the model (see Figure 2.2 below).

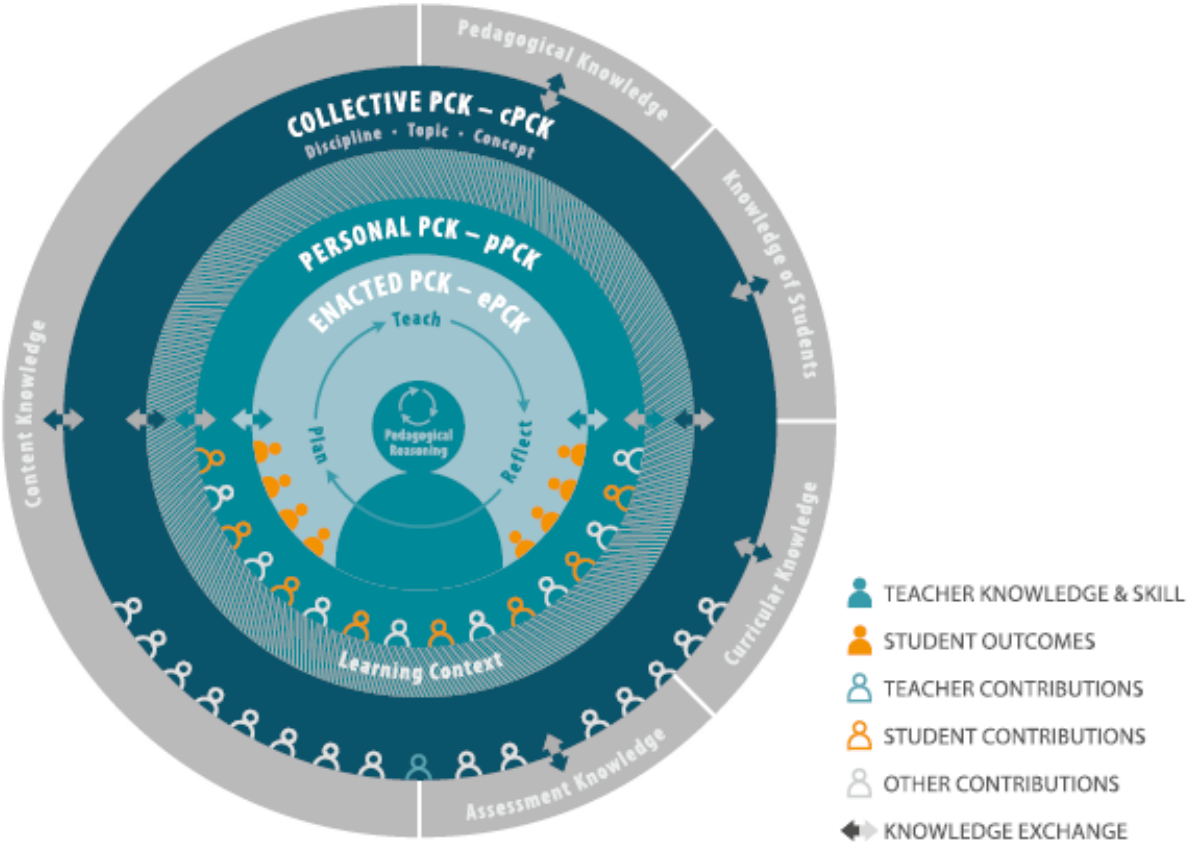



***Figure 2.2: Refined Consensus Model of PCK***

The RCM is appropriate for this study since it clearly identifies the knowledge and practice of an individual, and the broad knowledge that is held by multiple people in the profession. This is shown by the realms of PCK namely collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK) in the RCM (see Figure 2.2 above). The realm of cPCK is described as collective knowledge for teaching science, which is developed and shared among professionals (Carlson et al., 2019). This knowledge is public, and goes beyond what is available in academic writings, and includes the knowledge used by teachers. In this study, textbooks are regarded as collective PCK, because they are publicly available and used by teachers. Teachers who use textbooks draw from the PCK revealed in the textbooks to personalise their PCK through amplifiers and filters that determine/ influence the knowledge exchange

between realms. In the RCM, the learning context is identified as a major source of amplifiers and filters between broader PCK and teachers' knowledge and practice. Carlson et al. (2019) make explicit that learning context includes educational climate, a specific learning environment and individual learner attributes. In terms of learning environment, a teacher can choose not to do experiments or demonstrations that are outlined in the textbook, because there are no laboratories and resources in the school to perform the experiment or demonstration. This can be regarded as a limitation of collective PCK presented in textbooks, which is that the PCK revealed in textbooks is not applicable to some contexts such as rural areas. Also, textbooks can present representations that has limitations and can enforce a learner misconception which was not the intention of textbook authors. Hence it is important that teachers engage with the textbooks.

The knowledge drawn from collective PCK becomes part of teachers' personal PCK which is the knowledge and skills that teachers draw from to inform their enacted PCK. Enacted PCK is revealed in planning for instruction, actual teaching and reflection on the lessons (Carlson et al., 2019). This study will focus on enacted PCK, rather than the personal PCK of the teachers. This is mainly because enacted PCK is the one that has a direct impact on learners' outcomes (Akinyemi & Mavhunga, 2021). Furthermore, teachers enacted PCK relies heavily on personal PCK (Alonzo & Kim, 2016; Vollebregt et al., 2021). In addition to the fact that RCM distinguishes between realms of PCK, the model is crucial because it acknowledges the different grain sizes of PCK from discipline-specific to topic-specific to concept-specific PCK (Carlson et al., 2019). This study focuses on topic-specific PCK using the curriculum topic of electric circuits at the Grade Nine level under the subject of Natural Sciences. We acknowledge concept-specific PCK, hence we focused on the fundamental concepts

of voltage, current, and resistance in series and parallel circuits under the topic of electric circuits. It is worth noting that the RCM does not describe the components that characterise PCK with the realms. As such, I used PCK components proposed by Chan et al. (2019) to conceptualise collective PCK revealed in textbooks and the level at which teachers enact their own PCK. The components are knowledge and skills related to: i) curricular saliency; ii) learners' understanding of science concepts; and iii) conceptual teaching strategies including representations. The components are discussed in the next section.

## Discussion of PCK components

### i) Curricular saliency

The curricular saliency component requires a comprehensive understanding of the concepts of the topic as prescribed by the curriculum statements. This includes awareness of the pre-concepts that ought to be in place before teaching the topic, whether these concepts are from the previous grade or the previous topics in the same grade. The new concepts ought to be developed from pre-concepts. Furthermore, this component concerns the sequencing and interrelatedness of the concepts to support conceptual development (Mazibe et al., 2024). Lastly, this component also concerns the importance of the concepts in terms of the practical application of the concepts in life and connection to future concepts.

### ii) Learners understanding of science concepts

This component concerns the knowledge of learners' difficulties and misconceptions of electric circuits as reported in the diagnostic reports and literature. In addition, the

component includes addressing the challenges and misconceptions for effective instruction.

### iii) Conceptual teaching strategies and representations

This component concerns the knowledge of instructional strategies and representations that are topic-specific to present the content of the subject. Instructional representations include the use of multiple representations, such as diagrams, models, examples, simulations, analogies and demonstrations in order to present the fundamental concepts of electric circuits. The quality and limitations of the representations ought to be taken into consideration when selecting and using the representations. Regarding the instructional strategies, these include providing explanations for challenging concepts and the use of questioning in activities or discussions in order to encourage conceptual reasoning. The strategies that are selected and used should support conceptual development as opposed to rote learning. Furthermore, this component refers to the integration of the other components (Mavhunga & Rollnick, 2013), such as curricular saliency and learners' understanding of science concepts, as described above.

## 2.2.3 Development of teachers PCK

The RCM of PCK provides insight into how teacher PCK develops (Mientus et al., 2022). In the literature, researchers used RCM to investigate the development of teachers' PCK and practice during interventions that are presented in initial teacher education (Mavhunga & Rollnick, 2013) and professional development workshops (Vollebregt et al., 2021). The researchers placed interventions within the realm of collective PCK and investigated how the collective PCK presented in the workshops and initial teacher education contributed towards the development of teachers' PCK.

Sorge et al. (2019) investigated the impact of collective PCK on physics teachers' enacted PCK and found that collective PCK plays a role in developing teachers enacted PCK. Furthermore, the development of teachers' enacted PCK was moderated by teaching experience, motivational aspects, and self-regulatory skills, which were reported as amplifiers and filters for the translation of enacted PCK from collective PCK. Bayram-Jacobs et al. (2019) investigated the impact of curriculum materials on teachers PCK during a professional development programme. They reported that the curriculum materials contributed positively towards teachers' PCK and practice. If one places curriculum materials within the realm of collective PCK, then this supports the above discussion that collective PCK develop teachers' personal and enacted PCK as shown in the RCM.

In contrast to the above findings, literature shows that collective PCK presented in interventions does not always develop teachers' PCK. Ntuli and Mudau (2023) found that natural sciences teachers lacked content knowledge and PCK even after attending content workshops organised by the Department of Basic Education (DoBE). This concur with the findings by Poti et al. (2022), they found out that teachers PCK about electric circuits did not improve, even though the teachers attend content workshops at the begging of each term before teaching the topic. This implies that the collective PCK presented in the workshops was not exemplary, and had little or no influence on teachers PCK. We argue that collective PCK is not always exemplary, and can be basic or limited. Consequently, we started by investigating the quality of collective PCK as presented in textbooks before investigating its impact on teachers enacted PCK.

Teachers are not aware that they possess PCK, where some have never heard of the construct, while others remembered it as a theory that was used in their initial teacher training. This is similar to teachers' use of the textbook in such a way that the teachers might not be aware that textbooks can develop their knowledge of teaching abstract topics such as electric circuits. Karal and Alev (2016) revealed that textbooks were one of the curriculum materials that developed teachers' PCK. Although this study does not concern the how teachers PCK develops, it assumes that textbooks can develop teachers' knowledge provided that they present exemplary PCK. As a result, the study investigated the impact of textbooks on teachers enacted PCK. Research has been done on the impact of curriculum materials that are specifically designed for developing teachers' PCK (Bayram-Jacobs et al., 2019; Davis et al., 2014). However, there seems to be a paucity of literature on the impact of curriculum materials that are already in use such as textbooks.

### 2.2.4 Capturing and assessing PCK

Smith and Banilower (2015) argue that PCK cannot be observed directly, instead, researchers inferred teachers' PCK from observable behaviours such as written responses to questions, interview responses and teaching practice. Consequently, PCK researchers used different data sources including written questionnaires/tests/surveys, interviews, lesson plans or lesson observations to investigate teachers' PCK at different phases of the teaching cycle (Chan & Hume, 2019). The data sources were guided by the PCK components that researchers used in their study and the models that they adopted. Given that teachers' PCK is tacit and elusive, researchers developed instruments to capture and elicit teachers' PCK. The most commonly used instrument is the Content Representation tool (CoRe tool)

developed by Loughran et al. (2004). A CoRe tool is used to capture and portray teachers' content knowledge and how the teacher will make the content comprehensible for the learners. The CoRe tool requires teachers to first determine the main concepts termed “big ideas” and then complete eight prompts that probe teachers about content and strategies to teach the content. Mavhunga et al. (2016) aligned the prompts of CoRe tool to PCK components. For instance, under curricular saliency, the questions concerns the main concepts that learners must know, pre-concepts and why should learners learn the concept; under learners understanding of science, the questions concerns learners difficulties and misconceptions; and under conceptual teaching strategies, the questions concerns representations and instructional strategies to teach particular concepts within the topic.

Although the CoRe tool is a useful practical tool that capture and elicits PCK directly from teachers, its weakness is that it is time-consuming, training is required for teachers and it can be intimidating to teachers to complete (Kind, 2009). As a result, the CoRe tool was not used in this study to capture and elicit teachers' PCK. However, the prompts of CoRe tool were used as guidance to design interview questions that will elicit teachers' PCK about their lesson planning. In addition to the interviews, teachers' PCK was captured using classroom observations. In agreement with Park and kyung Suh (2015) where they note that classroom observations offer limited access to teachers' PCK as it is not possible to observe all aspects of teachers' PCK, this study used video-stimulated recall interviews to probe teachers about their actions. Teachers had to watch specific sections of their recorded video lessons and reflect on those sections. After capturing teachers' PCK through interviews and classroom observations, we assessed the quality of teachers' PCK using PCK rubrics. Textbook data was also analysed using the PCK rubric to determine the quality of PCK

revealed in the textbooks. In the literature, rubrics are used to assess teachers' PCK captured through questionnaires (Davidowitz & Potgieter, 2016), CoRe tool and interviews (Vollebregt et al., 2021) and classroom observations (Akinyemi & Mavhunga, 2021).

In this study, I used the PCK rubric template proposed by Chan et al. (2019). The template is generic (see Figure 2.3 below), and can be adapted for use in various topics to assess PCK at different grain sizes. The rubric is made up of five PCK components of knowledge and skills related to curricular saliency, learners' understanding of sciences, conceptual teaching strategies, integration between components and pedagogical reasoning. The study only used the first three components to design our rubric by adapting the pre-existing rubrics in the literature (Mazibe et al., 2024; Park et al., 2011). Four-point scale level was used with the lowest level being limited, followed by basic then developing and exemplary.

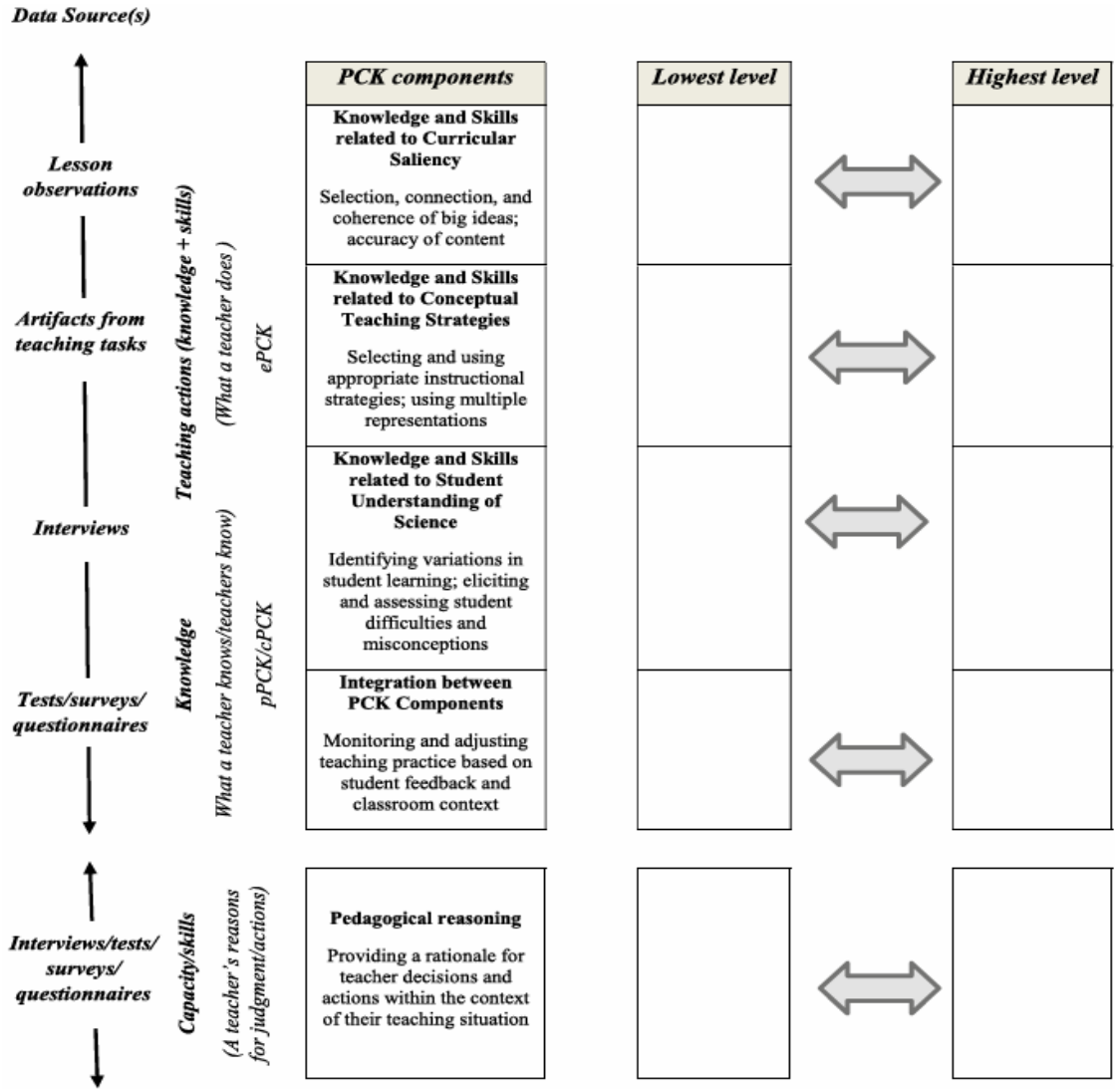



***Figure 2.3: Grand PCK rubric template by Chan et al. (2019)***

## 2.3 TEXTBOOKS AS EDUCATIVE CURRICULUM MATERIALS

Research shows that school textbooks have been analysed using different theoretical constructs for various purposes (Vojíř & Rusek, 2019). For instance, Ramnarain and Chanetsa (2016) analysed Grade Nine science textbooks to reveal how the nature of science is presented in the textbooks. However, research into the analysis of textbooks through the lens of PCK is minimal in the literature (Mazibe & Rollnick, 2023). PCK components are often analysed separately, where the focus is either on

one or two components. In this section, I review the literature of analysis of textbooks related knowledge components of conceptual teaching strategies, learners' understanding of science, representations and curricular saliency.

### 2.3.1 Textbook analysis

In terms of curricular saliency, it is reported that textbooks present the content knowledge and skills that are prescribed by the curriculum documents (Mazibe & Rollnick, 2023; Vojíř & Rusek, 2022). Sothayapetch et al. (2013) revealed that textbooks describe the relation between electric circuit concepts and introduce new concepts by relating them with pre-concepts. The interrelatedness of the concepts can make it easier for the learners to relate the concepts for better understanding. In addition to relating concepts with one another, textbooks also describe how science concepts are related to learners' everyday lives by stating applications of concepts in the real world (Qadeer, 2013). It can be inferred that textbooks can support teachers in developing their knowledge of curricular saliency.

Literature on learners' understanding reveals that some textbooks reveal learners' misconceptions (King, 2010; Zajkov et al., 2017). Given the nature of concept-specific PCK (Carlson et al., 2019), Develi and Namdar (2019) focused on the concept of force and examined how textbooks explain frictional force. These authors found that textbooks explain frictional force inadequately, and that there are often inconsistencies when the concept is applied in a variety of situations. The inconsistencies and inadequate explanations can induce misconceptions about frictional forces such as direction. Taibu et al. (2015) also indicated that the scientific language in textbooks can cause learners difficulties and misconceptions. Furthermore, they reported that the concepts of physics are not well represented in textbooks. Sometimes the textbook

makes use of representations that are problematic and become a source of learners' difficulties (Aregehagn et al., 2023).

To prevent misconceptions evident in textbooks or statements/ representations that can induce misconceptions, teachers need to evaluate textbooks (Gumilar & Ismail, 2023) before they teach and make learners aware of the difficulties that can arise because of how the content is presented or the misconceptions presented in the textbooks. This is essential because learners' understanding of science concepts is a fundamental knowledge component of teachers' PCK (Chan & Hume, 2019). Although textbooks can have conceptual errors and misconceptions, this is not the case for all textbooks. Jamil et al. (2024) revealed that textbooks can develop critical thinking skills through open-ended questions, comparison of concepts and encouraging conceptual reasoning. Mazibe and Rollnick (2023) noted that textbooks cautioned learners with documented misconceptions about fundamental concepts of electrostatics. For instance, the textbooks cautioned learners against the misconception of confusing vector characteristics and the polarity of charges when determining the magnitude of electrostatic force. This implies that certain textbooks can support teachers in preventing and addressing learners' difficulties and misconceptions about key concepts in science. If the textbook reveals limited knowledge of learners' challenges and misconceptions of science concepts, it is unlikely to contribute to the development of teachers' knowledge of learners understanding. The textbooks that reveal developing or exemplary PCK have a better chance of supporting teachers.

The role of representations in textbooks has been examined for their impact on learners' comprehension of scientific concepts. Preston (2019) and Vojíř and Rusek (2019) report that electric circuit diagrams presented in textbooks enhance learners'

understanding of electric circuit concepts and are useful to address learners challenge learners' of the concepts. Wong and Chu (2017) revealed that textbooks employ multiple representations that include textual descriptions, circuit diagrams, scientific models, mathematical equations and graphs to explain the electric current concept. They argue that utilising multiple representations has the potential to develop a meaningful and deeper understanding of the concept. Other researchers reveal that textbooks' representation of electric current is limited to two or three representations such as scientific models with analogies (Preston, 2019; Stocklmayer & Treagust, 1994). This limitation can constrain the depth of understanding that learners achieve. In some studies, the representations evident in the textbooks have explanatory texts that provide clarification about the concept presented to prevent misinterpretation (Aregehagn et al., 2023) that can induce difficulties or misconceptions. Furthermore, Gurung et al. (2022) report that textbooks provide support for interpreting and translating representations, as well as how to use most of the representations. This implies that textbooks can be educative by supporting teachers on how to use representations presented in the textbooks effectively.

The teaching strategies evident in the science textbooks have been analysed to determine whether they support the acquisition of factual or conceptual knowledge. Gumilar and Ismail (2023) focused on textbook laboratory activities and reported that the activities evident in the textbooks promote procedural knowledge by focusing on skills such as measurement, observations and manipulation of results. These kind of activities promotes factual knowledge as learners are likely to do the activities for verification of laws and theories. The absence of crucial skills such as stating variables, hypothesis or prediction of results and designing activities hinders the acquisition of conceptual knowledge (Gumilar & Ismail, 2023). Tunga and Jumadi

(2022) studied the different types of questions in textbooks. They reported that textbooks do not encourage critical thinking because of the exclusion of questions at evaluating and creating levels. Halawa et al. (2023) examined inquiry-based learning in textbooks and found that the textbook's activities focus on inquiry skills and not understanding inquiry. Furthermore, the activities in textbooks emphasise confirmed inquiry as opposed to guided inquiry. The implication of this is that the teachers who use this textbook might focus on the confirmed inquiry which promotes factual knowledge.

In contrast to strategies that promote factual knowledge, extant literature shows that there are textbooks that make use of strategies that promote conceptual knowledge (Jamil et al., 2024; Vojíř & Rusek, 2022). Dunne et al. (2013) revealed that the strategies suggested by textbooks can support teachers in implementing inquiry-based learning in classrooms by providing them with content knowledge, student-centred approaches and pedagogical practices. Vojíř and Rusek (2022) reported that the tasks in textbooks included both open-ended tasks and laboratory tasks that require critical thinking. Furthermore, the textbooks suggest explanations that encourage conceptual reasoning. It can be inferred that teaching strategies presented in textbooks promote both factual and conceptual knowledge. This implies that the textbooks can support teachers with opportunities for learning about strategies that promote critical thinking and conceptual reasoning. When the strategy suggested by textbooks encourages factual knowledge, the teacher can adapt the textbooks by adding the knowledge revealed in textbooks to engage learners in discussions that develop learners' conceptual knowledge and critical skills.

### 2.3.2 The Influence of textbooks on teachers PCK

According to Leshota (2020), teachers' use of textbooks is tacit, not deliberate. This means that teachers might not be aware of how the textbooks inform their knowledge of teaching (PCK). Literature shows that textbooks inform teachers PCK when they are planning lessons and teaching (Arias et al., 2016; Horsley & Sikorová, 2015). Teachers rely on textbooks for the content that should be taught in specific grades (Chen & Wei, 2015; Sikorova, 2011). Mitchell (2021) has revealed that teachers taught physics concepts that were explicitly stated in the textbooks but implicitly stated in the curriculum. This supports the notion that teachers use the textbook more than they refer to the curriculum statements for content that should be taught in specific grades. Furthermore, teachers' sequencing of the concepts is similar to the sequencing evident in the textbooks (Bergqvist & Chang Rundgren, 2017). In addition to curricular saliency, textbooks inform teachers' knowledge of instructional strategies (Horsley & Sikorová, 2015; Thobela et al., 2023). It is important to mention that teachers do not necessarily draw only from textbooks for instructional strategies, but that the textbook is a primary source and other materials are used to supplement the textbooks (Ridzuwan et al., 2024). Vojíř and Rusek (2021) indicate that teachers who use only textbooks rely on multiple textbooks to inform their teaching. Furthermore, the teachers who use textbooks are not limited to novice teachers as implied by other researchers (Orgoványi-Gajdos, 2015). Instead, the literature shows that experienced teachers use textbooks more than novice teachers (Bergqvist & Chang Rundgren, 2017; Vojíř & Rusek, 2021). This implies that textbooks inform PCK of both novice and experienced teachers.

Textbooks inform teachers' knowledge of representations. McDonald (2016) as well as Bergqvist and Chang Rundgren (2017) revealed that teachers relied heavily on the

representations that are suggested in the textbooks to present science concepts. Furthermore, the teachers' choice of textbooks was based on the quality of representations that they used. It is essential that teachers use some of the representations for classroom instruction and highlight the limitations of the representations. As discussed in the previous sections, textbook representations such as circuit diagrams can enhance learners' understanding of science concepts (Preston, 2019). Sikorova (2011) revealed that the activities, exercises and questions suggested by the textbooks were used by teachers to emphasise key concepts when teaching. The textbooks often provide the activities and exercises to be completed by the learners for comprehension of the concepts, however, the teachers use the activities and exercises as part of their teaching strategies not at the end of the lessons for assessment purposes (Mitchell, 2021; Thobela et al., 2023).

Teachers PCK is not a product of PCK presented in the textbooks (Roblin et al., 2018). Research shows that teachers adapt textbooks by omitting some concepts and adding some content of their own (Leshota, 2020; Thobela et al., 2023). Chen and Wei (2015) reported that teachers in their study decided not to conduct inquiry-based activities that were presented in the textbooks, because learners ought to have already done the content of the activities. Instead, the teachers opted to do demonstrations of their own. The adaptation of textbooks is vital given that the textbook activities and exercises might not be suitable for some classrooms due to contextual factors such as school infrastructure. The way teachers adapt and use textbooks is influenced by the teacher's PCK (Vojíř & Rusek, 2021). Therefore, textbook influence on teachers' PCK is dependent on various factors such as contextual factors and teachers' PCK. The teachers also use textbooks for reinforcement to emphasise some of the fundamental concepts (Mithans & Grmek, 2020).

Sun et al. (2009) reported that teachers who used standard-based textbooks suggested strategies to engage learners more than teachers who used low-rated textbooks. This supports the idea that textbooks should reveal developing or exemplary PCK in order to support teachers with teaching science content. It can be inferred that textbooks inform teachers' knowledge of PCK components such as conceptual teaching strategies and curricular saliency. However, the influence of textbook knowledge of knowledge of learners' understanding of teachers' knowledge is not often reported in the literature.

## 2.4 TEACHING AND LEARNING ELECTRIC CIRCUITS

### 2.4.1 Learners' misconceptions and difficulties of electric circuits

Learners' difficulties and misconceptions about simple electric circuits are widely researched (Cohen et al., 1983; Küçüközer & Kocakülah, 2007; Mbonyiryivuze et al., 2019; Shipstone, 1988). The most common difficulties and misconceptions are associated with voltage, electric current, and resistance (Liu et al., 2022), while other misconceptions concern analysing electric circuits as a system (Mbonyiryivuze et al., 2019).

The learners' alternative conception of voltage is that, without current, there will not be voltage (Kapartzianis & Kriek, 2014). This might be because learners do not view voltage as an independent variable, but rather, they think of it as a consequence of electric current (Cohen et al., 1983). Setyani and Handhika (2017) reported that learners misinterpreted Ohm's law equation as V=IR, where learners believe that in an open circuit, the current will be equal to zero and as a result, the voltage across the power source will be equal to zero according to the equation of V=IR (Setyani & Handhika, 2017). This was also reported by Aisahsari and Ermawati (2020), who

revealed that learners memorise physics formulas without a solid understanding of electric circuit concepts. A study by Liu et al. (2022) revealed that learners' perception of voltage is that it is an absolute measure at one point as opposed to being across two points of electric circuit components. This might be another cause of learners' perception that an open circuit does not have voltage, while they forget that voltage exist across electric circuit components such as cells.

Another misconception that learners have about voltage is regarding the total voltage provided by cells in series and parallel circuits, where learners often believe that, if a bulb is connected to two cells in a series connection in diagram one and in diagram two the bulb of same resistance as bulb in diagram one is connected to two cells in a parallel connection, the bulb will have the same brightness regardless of the type of circuit connection (M. Coetzee et al., 2022; Nkopane et al., 2011). This misconception is not only held by learners in high schools, but by pre-service teachers as well (Suryadi et al., 2020). Another misconception related to voltage is that learners often believe that the battery provides constant current not constant voltage, regardless of the way in which the components of the circuits are arranged (Cohen et al., 1983; Küçüközer & Kocakülah, 2007). Research shows that learners perceive the concepts of voltage, current and energy as the same concept instead of different concepts (Engelhardt & Beichner, 2004; Nkopane et al., 2011). This implies that learners lack critical thinking and conceptual reasoning of the concepts of electric circuits, and the way in which electric circuits function as energy systems.

Apart from the concept of voltage, research shows that learners hold misconceptions about electric current that are resistant to change even after instruction (Mbonyiryivuze et al., 2019). The most common misconception is that electric current that flows from

the positive terminal of the power source is consumed by the electrical components and less current will return to the negative terminal of the power source (Küçüközer & Kocakülah, 2007; Shipstone, 1988). This misconception is often regarded as *attenuation or weakening of the current model* (Sencar & Eryilmaz, 2004). Kapartzianis and Kriek (2014) used the framework of the conceptual change model in an intervention to address learners' misconceptions about electric circuits. The authors found that even after weakening the misconceptions in students' current model, many misconceptions persisted. The other alternative conception that learners have about electric current is that current flows from both terminals of the power source and clashes at electrical components such as the bulb and that's how the bulb gives off light energy (Aligo et al., 2021; Çepni & Keleş, 2006). Learners also hold the alternative conception that electric current is shared by electrical components equally irrespective of the resistance of the components (Sencar & Eryilmaz, 2004; Suryadi et al., 2020). This does not only reveal a limited understanding of electric current but also a limited understanding of the interrelatedness of the electric current with resistance.

Learners often perceive resistance as being caused by electric current, because they believe that electric current must be present for any resistance to exist (Engelhardt & Beichner, 2004; Kapartzianis & Kriek, 2014). This alternative conception may be due to learners' confusion about resistance with voltage and current arising from their interpretation of the mathematical equation of R=V/I (Liu et al., 2022). It would be better if the sequencing of concepts could be from voltage to current, which may explain the cause and effect. Then, resistance is taught after learners have a conceptual understanding of voltage and current. Also, it is important to clarify the mathematical equation of R=V/I from both mathematical and physics perspectives. From a mathematical perspective, a change in resistance (R) affects current (I) and

vice versa. But from a physics perspective, a change in current cannot affect resistance because resistance is a property of a resistor; it is not affected by a change in current. It is only change in resistance that affects the current.

The other alternative conception that learners hold is a parallel misconception regarding the resistance of resistors in parallel circuits and its relation to the current (Sencar & Eryilmaz, 2004). Learners' perception is that, as more resistors are added in parallel circuits, the total resistance in the circuit increases thereby decreasing the electric current (Cohen et al., 1983; Nkopane et al., 2011). Although this is correct for resistors in a series circuit, it is not true for resistors in parallel circuits. Another perception of learners when it comes to electric current is its relationship with resistance for resistors connected in parallel connection. Learners hold the view that electric current divides equally for resistors connected in parallel circuits without taking into account the resistance of those resistors in parallel connection (Küçüközer & Kocakülah, 2007). This misconception is regarded as a local reasoning model (Kapartzianis & Kriek, 2014). It is reported that parallel and local reasoning misconceptions are common among high school learners and teachers (Aligo et al., 2021).

Literature shows that learners have challenges when it comes to identifying which resistors are connected in series connection and which ones are connected in parallel connection (Aisahsari & Ermawati, 2020; Ivanjek et al., 2021). This difficulty has been consistently reported in the diagnostic report over the years (Department of Basic Education, 2021, 2022, 2023). The diagnostic report reveals that Grade 12 Physical Sciences learners are unable to interpret the circuit because they fail to identify which resistors are connected in a series connection, and which are connected in a parallel

connection (Department of Basic Education, 2021). This implies that Grade 12 learners lack the basic knowledge of electric circuit principles, which are taught in Eight and Nine under the subject of Natural Sciences. Furthermore, the diagnostic report reveals that Grade 12 learners experience difficulty concerning the effect of removing or adding a resistor in either a series or parallel circuit (Department of Basic Education, 2022). This is a persistent misconception that is reported in the literature referred to as sequential reasoning (Küçüközer & Kocakülah, 2007; Mbonyiryivuze et al., 2019). Learners also hold the view that, if there is a change in the circuit, this only affects the part where there was a change, not the entire circuit (Cohen et al., 1983; Kapartzianis & Kriek, 2014). Furthermore, learners do not integrate concepts when reasoning about the effect of removing or adding a resistor (Department of Basic Education, 2023).

It can be inferred that learners' misconceptions and difficulties about electric circuits are caused by learners' experience with electricity, everyday language, and lack of understanding of mathematics equations and physics concepts (Aisahsari & Ermawati, 2020; Setyani & Handhika, 2017). Furthermore, misconceptions can arise from teaching because teachers themselves hold the same misconceptions (Aligo et al., 2021; Moodley & Gaigher, 2019).

### 2.4.2 Teaching electric circuits

Teachers often regard electric circuits as a challenging topic when it comes to teaching and learning due to the nature of the concepts of the topic (Gunstone et al., 2009). This might be because learners have difficulties and misconceptions about the concepts of electric circuits as discussed in the prior section. For teachers to reveal exemplary PCK, they need to have an understanding of the difficulties and misconceptions about the topic. However, understanding learners' difficulties and

misconceptions does not mean that teachers have strategies that can effectively address the misconceptions (Gaigher, 2014). A local study by Moodley and Gaigher (2019) revealed that teachers tend to recommend a technical approach, emphasising facts, calculations and demonstrations as opposed to constructive approaches. The technical approach encourages rote learning as opposed to conceptual development. To develop conceptual understanding and critical thinking, teachers should use instructional representations and strategies that effectively tackle learners' challenges of the topic.

The utilisation of representations has been reported as an effective approach for enhancing learning understanding of electric circuits (Banda & Nzabahimana, 2021; Preston, 2019; Rankhumise & Imenda, 2014). Preston (2019) indicates that teachers who use circuit diagrams with detailed explanations support conceptual reasoning and address learners' learning difficulties. Rankhumise and Imenda (2014) reported that the use of bicycle analogy helped learners understand how electric circuits work. The findings concur with those of Korganci et al. (2015), who reported that the hose pipe and water analogy was useful when teaching electric current. Furthermore, they reported that the use of analogies and circuit models was effective compared to traditional teaching methods (Korganci et al., 2015). In addition to the use of representations such as analogies, diagrams and models, Ramnarain and Moosa (2017) reported that computer simulations address learners' misconceptions of electric circuit concepts.

In terms of strategies, constructive approaches that include problem-based learning and inquiry-based learning are recommended as effective strategies that can be used to teach electric circuits (Mbonyiryivuze et al., 2019). Amin et al. (2022) found that

using inquiry-based learning when teaching electric circuits developed critical thinking skills. In their study, learners were engaged in five learning stages, namely: asking questions, investigating, creating, discussing and reflecting. Textbooks can support teachers in implementing an inquiry-based learning approach (Dunne et al., 2013) and provide teachers with appropriate representations (Gurung et al., 2022) where this study concerns the influence of PCK revealed in textbooks on teachers enacted PCK.

## 2.5 CONCLUSION

This chapter presented literature concerning the construct of PCK, textbooks in science education and curriculum topic of electric circuits. Regarding the PCK construct, I discussed how PCK has been conceptualised using models that are made up of knowledge components. The most recent model is the refined consensus model (RCM) of PCK which served as a conceptual framework guiding the current study. Furthermore, I discussed the development of teachers' PCK from an RCM perspective and how teachers' PCK is captured and assessed. In terms of textbooks in science education, the chapter discussed textbook analysis guided by knowledge components of PCK that were used to conceptualise PCK in this study. The chapter also discussed how textbook knowledge influences teachers' PCK in science education. The last section was about electric circuits, where I discussed learners' difficulties and misconceptions about key concepts of voltage, current and resistance and electric circuits as a system, after which the section discussed instructional strategies and representations that are suitable to develop conceptual understanding and encourage critical thinking. The chapter to follow presents the research methodology.

# CHAPTER 3: RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

This chapter presents the methodology that underpins this study. It starts by introducing the research paradigm and then discusses the methodological approach, research design, and sampling strategies that were used in the study. The justification for the choice of research approach and design is provided, emphasising the strengths and limitations of the chosen design. Subsequently, the chapter provides details of the procedures for collecting and analysing the data, specifying the instruments that were used. This is followed by a discussion of quality criteria of how I ensured the credibility and trustworthiness of the research findings. Finally, the chapter addresses the ethical considerations that were considered during the research process.

## 3.2 RESEARCH PARADIGM

This study was approached from an interpretivism paradigm perspective. The ontology (nature of reality) that aligns with an interpretive approach is relativism, meaning that a single phenomenon has multiple realities rather than a single reality (Kivunja & Kuyini, 2017; Pham, 2018). The phenomenon of this study is PCK revealed in textbooks and the extent to which it influences science teachers' ePCK. In my experience of using curriculum materials, I realised that different textbooks do not necessarily present content in the same way. Furthermore, two teachers can use one textbook, but the way in which they draw from it to inform their ePCK may differ. This is because teachers adapt and interpret the textbooks differently to suit their teaching approach. Teachers' interpretation of textbooks can be attributed to pedagogical factors such as learning context.

The strength of the interpretivism paradigm lies in the depth and richness of insights that it provides (Maree, 2019). This approach allows researchers to deeply understand how individuals interpret phenomena and construct meaning (Kivunja & Kuyini, 2017). By adopting the interpretive perspective, I aim to gain a comprehensive understanding of how textbooks present the content of electric circuits in terms of PCK components and how science teachers use the textbooks when teaching the topic to Grade Nine learners. However, my interpretation of how the textbooks present the content and how teachers utilise the opportunities afforded by textbooks will be influenced by my personal experience and beliefs. This subjectivity is a recognised limitation of the interpretivism paradigm, as knowledge is influenced by the researcher's perspective (Pham, 2018). To address this limitation, I used a PCK rubric that was confirmed by supervisors to analyse data, thereby limiting researcher bias.

## 3.3 METHODOLOGICAL APPROACH

The qualitative research approach is suitable for exploring and understanding individuals' interpretations of social or human problems (Creswell & Creswell, 2017). As a result, this study adopted a qualitative research approach because the approach aligns with this study's nature and objectives. This study explores the impact of PCK revealed in textbooks on science teachers' ePCK when teaching electric circuits. As Chan and Hume (2019) indicate, most PCK researchers used a qualitative approach to examine the nature of teachers' PCK. This is because PCK is personal and unique to each teacher (Carlson et al., 2019). For researchers to gain an in-depth understanding of teachers' ePCK, they ought to get close to the teachers and use methods of data collection that will reveal teachers' ePCK.

One of the key characteristics of a qualitative research approach is getting close to participants, as the research takes place in a natural setting (Creswell & Creswell, 2017; Marguerite, 2006). This means that participants are observed in their context. This was the case in this study as I went to the teaching environment of the teachers to observe their teaching in the classroom and their interaction with the learners. Furthermore, interviews were used to elicit the teachers' ePCK and pedagogical reasoning that was not possible to observe in the classroom. Aspers and Corte (2019) defined the qualitative research approach as an iterative process where the researcher gains a deep understanding of the phenomenon under study as a result of getting close to the participants. Hence in this study, I made the effort to get close to the participating teachers to understand how they draw out PCK revealed in textbooks to develop their own ePCK in electric circuits topic. The choice of qualitative research approach was also influenced by the connection the approach has with the interpretivism paradigm, as both seek people's perceptions and experiences to understand how they interpret the meaning of phenomena (Thanh & Thanh, 2015).

### 3.4 RESEARCH DESIGN

I used a case study research design, defined as a type of qualitative research approach that seeks to reveal meaning, investigate processes and gain an in-depth understanding of a single case or multiple cases (Creswell & Poth, 2016; Marguerite, 2006). The case in this study is Grade Nine Natural Sciences teachers and the textbooks that they used when teaching electric circuits. An exploratory multiple-case study was adopted, with four independent cases, where each teacher was treated as a separate case. The benefit of a case study design is that it allows multiple methods to collect and analyse data (Cohen et al., 2018; Creswell & Poth, 2016), which will provide me with an opportunity to triangulate data so as to enhance the trustworthiness

of the findings (Maree, 2019). Teachers' data was collected through classroom observations and interviews, while content analysis was done for the textbooks. For analysing data, two rubrics were utilised to reveal the quality of PCK presented in textbooks and teachers' ePCK, respectively. The limitation of a case study design is that the findings of this study only apply to the participants of this study and not the entire population of science teachers who use the textbook. However, the findings can be used to generalise towards a theory (Cohen et al., 2018) that emerges about the impact of PCK presented in textbooks on science teachers ePCK.

### 3.5 SAMPLING

Given that the study followed a case study design, it used non-probability sampling because the study focuses on a small-scale sample. According to Cohen et al. (2018), non-probability sampling is used when the researcher deliberately chooses specific individuals, fully aware that it represents itself not a wider population. The participating teachers were sampled from the population of Grade Nine Natural Sciences teachers within the Sekhukhune East District in Limpopo Province. Two types of non-probability sampling strategies, namely convenience and purposive sampling strategies were used. The strategy of convenience sampling is utilised when the researcher selects individuals who are easy to reach and available to participate in the study (Cohen et al., 2018). I approached five different schools that were closest to me and invited seven teachers to participate in the study. All seven teachers agreed to participate and signed a consent form. Unfortunately, one teacher pulled out of the study before I could collect data. The teacher said that she is not comfortable teaching the physics section of the Natural Sciences. Furthermore, she said she lacks content knowledge and that she usually asks a physics teacher to teach the electric circuits section. As a result, she did not participate.

The purposive sampling strategy is utilised when the researcher selects participants based on specific requirements and particular characteristics (Cohen et al., 2018). This is because the participants can purposively provide valuable insight into the research problem and the phenomenon that is being studied (Creswell & Poth, 2016). In this study, the phenomenon that was investigated is the PCK revealed in Grade Nine Natural Sciences textbooks and how that impacts teachers' ePCK. Therefore, the main criterion used was that the participating teachers must be teaching Grade Nine Natural Sciences and use textbooks as part of their curriculum materials when teaching the subject. When I invited the teachers to participate in the study, I only selected teachers who have been using a textbook when teaching Natural Sciences. The six remaining teachers invited to participate met the criteria and data was collected from all the teachers. When I was collecting data, I realised that two of the teachers rarely used the textbook in class. The teachers did not seem to value the PCK revealed in textbook and used other resources even though they stated that they used textbooks when I invited them to the study. This was further confirmed in the interview when the teachers stated that textbooks do not have sufficient content and they drew more from other curriculum materials. As a result, I was left with four teachers who used the textbook frequently when they were teaching and stated that they used it in planning the lesson too. See Table 3.1 below for the biographical information of the teachers.

For the selection of textbooks, three Grade Nine Natural Sciences learners' books were sampled, as they were the textbooks in use by the participating teachers. All textbooks had a teachers' guide, but the participating teachers only used the learner's textbook hence data was only collected from learners' textbooks. Pseudonyms were assigned to the teachers, as well as the textbooks that were labelled as Textbook A,

B and C. Textbook A was the most commonly used, with three of the four teachers using it. Textbooks B and C were each used by only one of the teachers. See Table 3.1 below for further details.

***Table 3.1 Biographical information of teachers***

| **Teachers names** | **Gender** | **Qualifications and teaching experience** | **Textbooks that the teacher used** | **School and type of resources** |
|---|---|---|---|---|
| 1. Nkatego | Female | BSc General (physics II)<br>PGCE (life sciences)<br>1 year of teaching Natural Science | Textbook A | School One<br>Poorly resourced |
| 2. Victoria | Female | BA Life Sciences (no undergraduate physics)<br>2 years of teaching Natural Sciences | Textbook B | School Two<br>Poorly resourced |
| 3. Robben | Male | BSc Chemistry (physics II)<br>PGCE (physical sciences)<br>2 years of teaching Natural Sciences | Textbook A<br>Textbook C | School Three<br>Poorly resourced |
| 4. Steve | Male | SPTD (Natural Sciences)<br>ACE Sciences<br>30 years of teaching Natural Sciences | Textbook A | School Four<br>Poorly resourced |

The table above shows pseudonyms that have been used to protect the teachers' identities. The names are Nkatego, Victoria, Robben and Steve. When this study was

conducted, Nkatego, Victoria and Robben had one or two years of experience teaching Natural Sciences, and Steve had 30 years of experience teaching the subject. Except for Victoria, the rest of the teachers had physics or natural sciences as part of their undergraduate degrees. School one was large, with four Grade Nine science classes that had about 60 learners each. On the other hand, schools two, three and four were small schools with a total of five to eight teachers in the schools for all the subjects. The teachers in small schools have to prepare for different subjects from Grades eight to twelve; this affects their preparation for Natural Sciences and the topic of electric circuits. All the schools were poorly resourced with no laboratories and a lack of resources that support teaching and learning such as use of computer simulations, models and charts. The schools rely on textbooks as the main curriculum materials for teaching and learning.

## 3.6 DATA COLLECTION

### 3.6.1 Data collection from textbooks

Data was collected from three Grade Nine Natural Sciences textbooks to address the first secondary research question:

- How do the Natural Sciences textbooks present the prescribed content of electric circuits concerning the selected PCK knowledge components?

Natural Sciences textbooks are divided into knowledge areas of life and living, matter and materials, energy and change and lastly earth and beyond. Under each knowledge area, there are different topics. The topic of electric circuits falls under the strands of energy and change. I collected data from all the pages that cover series and parallel circuits. For each textbook, the pages that present the topic were recorded in one document. These pages included the presentation of content in a written and

visual format. The document with all the pages of the topic was then used as data that represents a particular textbook. I then conducted a content analysis of the textual data. According to Hsieh and Shannon (2005), qualitative content analysis is defined as *"a research method that entails the subjective interpretation of textual data by systematically coding and identifying themes*" (p. 1278). In this study, PCK components were used as pre-determined themes to present the data from the three textbooks. The PCK components are knowledge of *i) curricular saliency; ii) learners' challenges; and misconceptions of science concepts and iii) representations and conceptual teaching strategies* (section 2.2.2 provides an elaboration of these components).

### 3.6.2 Teachers

Data was collected from four Grade Nine Natural Sciences teachers using classroom observations and interviews to address the secondary research questions that follows:

- How does the PCK revealed in Natural Sciences textbooks impact in-service teachers PCK when preparing to teach electric circuits?
- How does the PCK revealed in Natural Sciences textbooks impact in-service teachers' enacted PCK when teaching electric circuits to Grade Nine learners in the classroom?

### Classroom observations

The teachers who participated in this research were observed teaching electric circuits to Grade Nine science learners in the classroom. The teachers were not instructed to teach in any way. Instead, they were encouraged to teach as though I was not present.

I chose to start with observations so that the teachers do not use the interview questions as a guide to prepare the lesson and teach in a way that they think is how I want them to or that is how I want them to use the textbooks when teaching. There was also no discussion of textbooks before observations, such as how textbooks are used in teaching or what is good or bad about textbooks. I observed only one lesson from each of the three teachers, Nkatego, Victoria and Steve, where they taught the entire topic of series and parallel circuits in a lesson of 60 minutes. Robben on the other hand, was observed in a double lesson that took about 120 minutes, 60 minutes for each lesson. I recorded all the lessons without interfering in any way.

The strength of classroom observations is their potential to provide the researcher with valid and authentic data to gain an in-depth understanding of the phenomenon (Cohen et al., 2018). The observations allowed me to capture aspects of teachers' ePCK that were not possible through methods such as interviews or questionnaires. Furthermore, the observations were recorded, allowing for repeated viewing during data analysis. In the recorded videos, I looked for specific events that were connected to components of PCK that guided the current study. If the observations had not been recorded, I could have easily missed some aspects of teachers' ePCK because of being distracted during the observations. The data was transcribed and analysed using the PCK rubric.

**Interviews**

Interviews were conducted after the teachers completed the teaching of electric circuits. The interviews were divided into two parts, semi-structured interviews and video-stimulated recall (VSR) interviews. I began with a VSR interview and then proceeded to do a semi-structured interview. VSR interview is a research method where participants watch a video of their teaching and the researcher asks them to

reflect on the events that occurred at that particular time (Nguyen et al., 2013). Before the interviews, I looked for sections where the teachers could reflect on their teaching and get the reasons behind why they taught in the they did. During the interview, I played the video of their lessons to remind them of the events and asked them to reflect on those specific sections. For instance, if the teacher used a representation from the textbook and made some changes to it, I asked them to reflect on that. The goal was to gain an idea of how the textbooks were used and if they used only a specific section in the textbook, why they did that. A semi-structured interview took place immediately after the VSR interview. The goal was to gather data that reveal teachers' use of textbooks when planning to teach electric circuits. The interviews were audio recorded and transcribed for data analysis.

### 3.7 DATA ANALYSIS

The collected data was analysed using two PCK rubrics to determine the quality of PCK revealed in textbooks and teachers' ePCK. I designed the rubrics using the PCK rubric template that is proposed by Chan et al. (2019). I made use of three components suggested in the template namely knowledge related to *i) curricular saliency; ii) learners' challenges and misconceptions of science concepts; and iii) representations and conceptual teaching strategies*. The four-point scale was used to assess the competence and knowledge in the components that range from *limited*, to *basic*, to *developing* and *exemplary*. For the description of knowledge within the components, I adapted existing PCK rubrics by Park et al. (2011) and Mazibe et al. (2023), who used PCK rubrics to determine the quality of science PCK in different science topics on a four-point scale. Mazibe et al. (2023) used rubric to assess teachers ePCK in physics topic of electrostatics in South African classroom (see Figure 3.1 below for original rubric). In Figure 3.2 below, there is an example of the PCK rubric used to analyse

collective PCK revealed in textbooks for knowledge of conceptual teaching strategies and representations. Full rubrics for assessing PCK revealed in textbooks and teachers enacted PCK for this study appear in Appendix I and II.

The first thing I did was to keep the number of points used to describe the knowledge within the component the same. The points were about using questions, explanations, strategies and representations to present the content of the physics topic. The revealed PCK rubric for the textbook has the same points as the original rubric by Mazibe et al. (2023). What is different is the description of the points because the textbook presents static knowledge, and the original rubric was used to assess teachers' ePCK, which is dynamic. The description of knowledge of components was undertaken in consultation with various resources in the literature that reported on textbook analysis (Aregehagn et al., 2023; Mazibe & Rollnick, 2023).

Regarding the questions, I changed the description to whether the textbook questions support the conceptual development of electrical circuit concepts. For explanations, I changed to whether the textbook provides explanations for important and challenging concepts. In terms of the teaching strategies, I changed it to whether the teaching strategies suggested by the textbooks support conceptual reasoning and critical thinking. Mazibe et al. (2023) referred to algorithms in the original rubric because electrostatics has quantitative aspects. For the rubric of PCK revealed in textbooks, I changed the algorithm to rote learning to determine if the textbook encourages rote learning only or if it also encourages conceptual reasoning. Lastly, for representations, I changed to whether the representations evident in textbooks have explanatory texts or not. After adapting the original rubric, I shared it with the supervisor and co-supervisor, who are experienced science educators, in order to confirm whether the

adaptations were valid. The supervisors' comments helped me refine the descriptors of the PCK components in the rubrics.

**Figure 3.1: Mazibe et al. (2023) original rubric for conceptual teaching strategies and representations.**

| **PCK components** | ***Limited*** | ***Basic*** | ***Developing*** | ***Exemplary*** |
|---|---|---|---|---|
| Knowledge of conceptual teaching strategies and representations | • Questions are not used to involve learners, making the lessons completely teacher centered.<br>• Explanations are absent.<br>• The strategies support algorithms rather than conceptual understanding.<br>• The strategies lack the use of representations and focus on important and difficult concepts. | • The strategies seldom involve learners in the lesson through questions.<br>• Explanations are seldom provided.<br>• The strategies tend to support algorithms rather than conceptual understanding.<br>• The strategies include the use of a representation while explaining a few important and difficult concepts. | • The strategies sufficiently involve learners in the lesson through questions.<br>• Explanations are sufficiently provided.<br>• The strategies sufficiently support conceptual understanding while encouraging algorithms where necessary.<br>• The strategies include the use of various representations while explaining important and difficult concepts. | • The strategies appropriately involve learners in the lesson through questions.<br>• Explanations are appropriately provided.<br>• The strategies appropriately support conceptual understanding while encouraging algorithms where necessary.<br>• The strategies include the use of various powerful representations while explaining important and difficult concepts. |

***Figure 3.2: Revealed PCK for knowledge of conceptual teaching strategies and representations.***

| **PCK components** | ***Limited*** | ***Basic*** | ***Developing*** | ***Exemplary*** |
|---|---|---|---|---|
| Knowledge of conceptual teaching strategies and representations | • The questions evident in the textbook do not support conceptual development<br>• The are no explanations and discussions for important and challenging concepts<br>• The teaching strategies are technical and do not encourage conceptual reasoning<br>• The representations do not have explanatory texts and are specific to important and challenging concepts | • The questions evident in textbooks seldom support conceptual development<br>• There are seldom explanations and discussions<br>• The teaching strategies support rote learning, not conceptual reasoning and critical thinking<br>• There are few representations with explanatory texts | • The questions evident in the textbook are sufficient to support conceptual development<br>• There are sufficient explanations and discussions provided<br>• The teaching strategy sufficiently supports conceptual understanding while encouraging rote learning<br>• There are various representations with explanatory texts and discussions | • The questions evident in the textbook support conceptual development and encourage critical thinking<br>• There are explanations and discussions provided appropriately<br>• The teaching strategies suggested show an attempt to work towards inquiry and support conceptual reasoning and critical thinking<br>• There are multiple uses of representations for important and challenging concepts with explanatory texts and discussions |

I conducted an in-depth qualitative content analysis in order to investigate the opportunities presented by the textbooks to develop teachers' ePCK in the selected components. The analysis is for the three textbooks and is presented in Chapter 4. In Chapter 5, I present an in-depth analysis looking for evidence that reflects teachers' enactment of the collective PCK presented in textbooks in their practice.

## 3.8 QUALITY CRITERION

The key concepts that must be considered to ensure that qualitative research findings are trustworthy are credibility, confirmability, dependability, and transferability. Credibility involves ensuring that the participant's perceptions and experiences or events correspond to the way in which a researcher presents them in the research report (Marguerite, 2006). To guarantee the credibility of the findings, I used triangulation, which concerns using multiple data sources to collect data to comprehensively understand the phenomenon (Creswell & Creswell, 2017). Data was collected using interviews and classroom observations. The benefit of using multiple methods to collect data is that the limitation of one method is mitigated by the strength of another method (Bans-Akutey & Tiimub, 2021). Classroom observations were used as a primary source of data collection. However, since it is not possible to observe all aspects of teachers' ePCK and infer pedagogical reasoning through observations, I used interviews to probe teachers about planning and reflection on the lessons. The use of triangulation also ensures the confirmability of the research findings (Bans-Akutey & Tiimub, 2021). Confirmability refers to the degree to which the participants, rather than the researchers' bias, shape the research findings (Maree, 2019).

Dependability refers to whether the researcher clarifies the instruments utilised to collect and analyse the data (Marguerite, 2006). In order to ensure dependability, I

adapted the interview questions from the CoRe tool validated by Loughran et al. (2004). The interview questions were shared with my supervisor to ensure they aligned with the study's objectives. It was important to link the questions to the PCK revealed in textbooks as the questions of the CoRe tool are meant to examine the nature of teachers' PCK, and in this study, the questions were supposed to include the use of textbooks. For instance, after asking teachers about representations they used to teach specific concepts, the next question concerned teachers' perception of the representations evident in textbooks, if teachers used those representations, and how they used them. Data was analysed using rubrics designed using a PCK rubric template proposed by Chan et al. (2019). See the previous section (2.7 data analysis) for clarity about the rubric's design. Furthermore, audio and video recordings were made, and the data transcription was made available to the supervisors. The comments and meetings with the supervisors about data analysis caused me to review my interpretation of the data and link the data to the rubric. The use of rubrics and meetings with supervisors reduced researcher bias.

Lastly, in order to ensure the transferability of the research findings, I provided a detailed description of this study's context, background and phenomenon in sections 1.3 and 1.4 of Chapter 1. In Chapter 2, I presented a detailed description of the phenomenon of the study, PCK. I discussed the development of PCK throughout the years, instruments used to capture and analyse teachers' PCK and how RCM of PCK (see section 2.2.2) applies to this study. Furthermore, the components of PCK were discussed to make it easy for the reader to know what each component entails. Through the components, I investigated the collective PCK revealed in textbooks and the level at which teachers enact their own PCK.

## 3.9 ETHICAL CONSIDERATION

When conducting research, it is important to consider ethical issues at various stages of the research process. Creswell and Creswell (2017) outline these stages which include before commencement of the study, the beginning of the study and when data is collected, analysed and stored. Before the commencement of the study, I applied for ethical clearance from the institution of the University of Pretoria. Upon receiving approval, I approached the Limpopo Department of Basic Education to request permission to conduct the study at Sekhukhune East District schools. The permission was granted with conditions (see appendix III). To compile with the conditions of the approval, I approached Circuit offices and schools concerned. The Circuit Manager permitted me to conduct the study in any of the schools, provided that I made arrangements with the school. Subsequently, the school principals provided their consent for the study to be done at their respective schools. At the beginning of the study, the participating teachers, learners and the parents of the learners were given a consent form. The consent form clearly stated the aim and purpose of the study, procedures and the conditions of taking part in this study (see appendix IV). I informed the participants that their participation was voluntary and that if they want to withdrew, they can do so in writing or verbally at any point during the study. When collecting data, I reminded the participants about the procedure. The rights of the participants were respected during the process. When analysing, reporting and storing data, I ensured that the participants' information was treated confidentially. Pseudonyms were used in place of participants' real names and, the names of the schools and circuits where they were stationed were not mentioned at any point.

## 3.10 CONCLUSION

This chapter presented the research methodology, where I outlined the research paradigm, approach and design. This was followed by the sampling techniques that were used to sample participants from the population of Natural Sciences teachers at Sekhukhune East District. I then discussed the instruments that were used for the current study. Furthermore, I discussed how I ensured the quality criterion of research findings and ethical considerations. The next chapter presents the analysis of the PCK revealed in the sampled Natural Sciences textbooks.

# CHAPTER 4: PCK REVEALED IN THE TEXTBOOKS

## 4.1 INTRODUCTION

In this chapter, I present an analysis of Grade Nine Natural Sciences textbooks using the theoretical construct of PCK to reflect on the PCK revealed in the textbooks. The purpose of the analysis is to investigate the opportunities afforded by textbooks to contribute to the development of teachers' PCK when they teach the topic of electric circuits. This will address the first secondary question: How do the Grade Nine Natural Sciences textbooks present the prescribed content of electric circuits regarding selected PCK components? I start by discussing how the textbooks are analysed to reveal the quality of PCK presented in them. This is followed by a presentation of each textbook as a case study. The chapter concludes by presenting the quality of PCK revealed in textbooks using a table and a brief discussion.

## 4.2 ANALYSIS OF PCK REVEALED IN THE TEXTBOOKS

This section expands on how textbooks are analysed using components of PCK and rubric to determine the quality of PCK revealed in textbooks. Content analysis was used to analyse data using PCK components suggested in the grand PCK rubric, namely: *(i) knowledge of curricular saliency; (ii) knowledge of learners' understanding of concepts; and (iii) conceptual teaching strategies, including representations* (Chan et al., 2019) as themes. To assess the *knowledge of curricular saliency* revealed in the textbook, I looked for the presentation of content as prescribed by the curriculum, sequencing and interrelatedness of concepts and the importance of concepts in terms of real-life application and connection to future concepts. In terms of *knowledge of learners' understanding of science concepts*, I looked for the presentation of concepts that are documented as difficult in the literature and diagnostic reports and whether

the textbook caution teachers and learners about the challenging concepts. Regarding *knowledge of conceptual teaching strategies and representations*, I looked for explanatory texts, questions, discussions and explanations of the key concepts with reference to the representations and approaches used in the textbooks. See Table 4.1 below that provide summary of the examples for all the knowledge components.

***Table 4.1: Example of evidence that reflects PCK components***

| **PCK component** | **Aspects of the component** |
|---|---|
| Curricular saliency. | • Awareness of pre-concepts<br>• Development of new concepts from pre-concepts<br>• Sequencing and interrelatedness of the key concepts<br>• The importance of the concepts in terms of application and connection to future concepts<br>• Presentation of content and skills as prescribed by the curriculum |
| Learners understanding of the concepts. | • Presentation of concepts in a way that can prevent and address learners' difficulties and misconceptions documented in literature and diagnostic reports<br>• Statements that caution learners about difficulties/ misconceptions for key concepts (e.g current is not used up by resistors) |
| Conceptual teaching strategies including misconceptions. | • The teaching strategies/ approaches suggested can enhance the conceptual development of concepts<br>• Adequate discussions or explanatory texts for key concepts<br>• The use of questioning in discussions or activities that support conceptual development |

| | |
|---|---|
| | • Extensive use of representations such as diagrams, models, analogies, demonstrations to present key concepts |

To assess the quality of PCK revealed in the textbook, I used the PCK rubric developed for the purpose of this study (see section 3.7 of Chapter 3 for the discussion of the rubric). Regarding the content of electric circuits, I was guided by the curriculum to select three fundamental concepts for Grade 9 electric circuits. The fundamental concepts are voltage, current, and resistance for cells and resistors connected in series and parallel connection respectively. The concepts are analysed together under series and parallel circuits for each of the PCK components.

## 4.3 CASE STUDY ONE – TEXTBOOK A

Textbook A is commonly used by the schools in the Sekhukhune East District. The textbook covers the content prescribed by the curriculum for Grade Nine Natural Sciences, including the study topic, electric circuits. The Department of Basic Education (DoBE) provides the textbook to all schools in print format. There are no electronic copies available. Three of the four participating teachers in this study, namely Nkatego, Robben and Steve, used this textbook in the classroom when teaching electric circuits hence the textbook is analysed to investigate the opportunities that it affords teachers to teach electric circuits, which addresses the first secondary research question.

### 4.3.1 Knowledge of curricular saliency

The textbook authors reveal an awareness of the knowledge that must be in place before teaching series and parallel circuits by revising concepts related to fundamental concepts of voltage, current, and resistance. For instance, the difference between

series and parallel circuits is revised by stating that a series circuit has one pathway for current to flow while a parallel circuit has two or more pathways for current to flow, as covered in the previous grade. The new concepts are adequately developed from pre-concepts. This is evident when voltage is briefly revised as covered in the previous topic before presenting voltage for cells in circuits. Current and resistor are also revised briefly before presenting current for resistors in series and resistors for the connection of resistors in series and parallel circuits respectively. In the preceding section, the textbook discusses resistors and factors that affect resistance.

The sequencing of key concepts evident in the textbook is from voltage to current for series and parallel circuits. The textbook presents the concept of voltage across cells first and then voltage across resistors thereafter. For cells in a series connection, the textbook states that the more cells are connected in series, the higher the voltage across the battery. This was to explain that the voltage across the battery is the sum of the voltage across the individual cells in a series connection. After presenting the voltage across cells in a series connection, the textbook presents the voltage across resistors in a series connection. It clearly states that the total voltage across the battery equals the sum of voltage across all the resistors. The same presentation and sequencing were done for cells and resistors in parallel circuits. This is regarded as logical sequencing, according to the revealed PCK rubric. Furthermore, the sequencing can make it easy to reason about voltage in circuits, as opposed to current, because it discusses voltage in detail first and current after.

In line with the revealed PCK rubric, the textbook adequately explains the interrelatedness of the concepts of voltage, current, and resistance as prescribed in the curriculum. Voltage is related to resistance for resistors connected in series circuit

connection. This is done by explaining that, “the greater the resistance of a resistor, the greater the voltage across it”. Voltage is also related to energy. It is stated in this textbook that the voltage indicates the amount of energy required to move a certain amount of charge through the resistor. The relation between voltage and energy is further explained using analogies for series and parallel circuits. For resistors in series circuits, the textbook explains that the battery has the amount of energy the resistors use, where the resistor converts the electrical energy to other forms of energy. The current concept is related to resistance for both series and parallel circuit connections. For series circuits, the textbook states that the current decreases as more resistors are added. It is not stated that as more resistors are added, the higher the resistance which means that less current will flow. But for parallel circuits, it is clearly stated that, “the greater the resistance of the resistor, the less current will flow through the resistor”. Although the current is adequately related to resistance, it is not related to voltage.

In terms of the importance of learning about the key concepts, there is evidence of the application of electrical circuits by discussing lighting systems in homes. The textbook states the advantage of connecting bulbs in parallel circuits by stating that if the filament of one bulb fuses, the other bulbs will continue to glow unlike in series circuits. In addition, the importance of learning about circuits is evident when the textbook discusses the disadvantage of connecting more resistors in parallel connection. In the discussion, it is stated that as more resistors are connected in parallel connection, the current increases which poses a real danger. Furthermore, the textbook states that the next section will cover safety devices that will address this danger. This is *exemplary* according to the revealed PCK rubric as the relevance scaffold towards understanding the concept of current.

In conclusion, textbook A knowledge of curricular saliency is allocated an *exemplary* level on the revealed PCK rubric. This is based on awareness of the pre-concepts, linking or developing new concepts from pre-concepts, relevance of concepts, logical sequencing, and explanation of interrelatedness of concepts as discussed in the above paragraphs. Moreover, the textbook presents the concepts that are prescribed for electric circuits by the curriculum documents.

### 4.3.2 Knowledge of learners understanding of science concepts

The difficulty documented in the literature about voltage across cells is that learners believe that the battery provides the same voltage irrespective of the arrangement of cells (Engelhardt & Beichner, 2004). The textbook includes a statement that can address this difficulty by stating that "*connecting cells in parallel does not increase the voltage of the battery. It does, however, make the battery last longer*". It is important to emphasise this aspect, given that the voltage across the cells increased in series as more cells were added. Learners might for example think it is the same with cells in parallel. Furthermore, there is a practical investigation of measuring voltage across the cells in series and parallel circuits. This reveals *developing* PCK according to the revealed PCK rubric since the textbook provides a statement that cautions learners about the difficulty of the concept of voltage across cells in electrical circuits and suggests practical investigation for the concept.

The common misconception about electric current is that learners believe that current is used up by the components, and less current returns to the battery (Sencar & Eryilmaz, 2004). The textbook presents electric current through resistors in series in a way that can address learners' misconceptions of the concept. There is a practical investigation activity where electric current is measured before three resistors,

between the resistors, and after the resistors. A conclusion is given that the electric current is the same at any point in a series circuit. In addition to the practical investigation, there is an activity where there is a question about the reading on the ammeter before a resistor, between resistors, and after the resistors. Compared to the revealed PCK rubric, the textbook reveals *developing* PCK because there are two ways to address learners' misconceptions, and the statement cautions against such a misconception.

The other common misconception learners have is about electric current through resistors' parallel connection. Learners believe that the electric current will split equally in order for the resistors connected in parallel irrespective of the resistance of the resistors connected in parallel (Cohen et al., 1983). Similar to the presentation of electric current through resistors in a series circuit, there is practical investigation and activity that might address the misconception. In the activity, the first question has two resistors of equal resistance and the second question has two resistors of different resistance (see Figure 4.1 below). The teacher can caution learners against the difficulty if they do the activity. In addition to that, there is a statement about resistors in parallel circuits that states that “the higher the resistance of a resistor, the smaller the current through it. The lower the resistance of the resistor, the larger the current through it”. This is regarded as *basic* PCK according to the revealed PCK rubric because it provides standardised phrases without explanation or expanding on the statement.

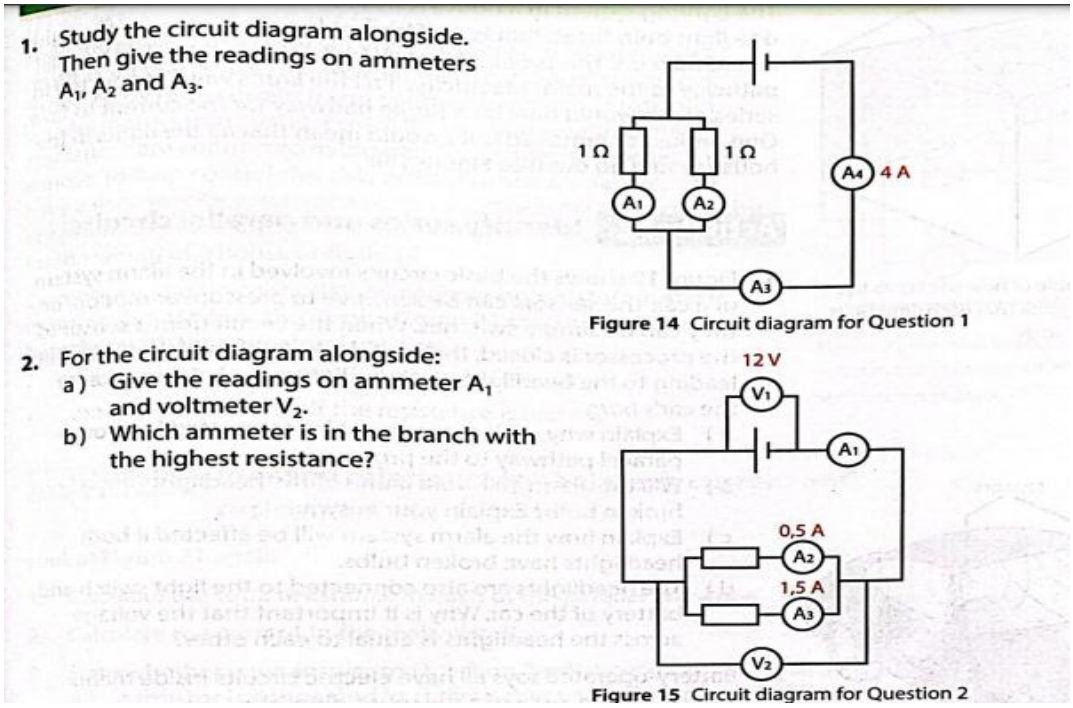



**Figure 4.1: Textbook A problems in exercise**

In conclusion, textbook A presents the content of electrical circuits in a way that can address learners' common misconceptions and challenges. No misconceptions or conceptual errors are evident in the textbook; hence, it is not allocated a *limited* level on the revealed PCK rubric. Some practical investigations and activities can address learners' misconceptions and challenges of electrical circuits. The statements provided in the textbooks caution learners about some of these misconceptions and challenges. For this reason, the textbook is allocated a *basic* level in the revealed PCK rubric. The textbook does not reveal exemplary PCK, because there are common misconceptions that are persistent to change that are not addressed or statements that caution against these misconceptions. The misconceptions are constant current source and local and sequential reasoning (Engelhardt & Beichner, 2004). Furthermore, the textbook does not elaborate on explanations in order to provide clarity for important and challenging electrical circuit concepts.

### 4.3.3 Knowledge related to conceptual teaching strategies and representations

The textbook uses circuit diagrams and analogies to present key concepts of voltage, current and resistance in series and parallel circuits. Regarding the circuit diagrams, the textbook provides schematic diagrams for resistors in electrical circuits. This is done at the end of practical investigation activities and for assessment purposes in activities. Figure 4.2 below shows a circuit diagram used for the concept of voltage in a series circuit at the end of the practical investigation. It is evident from the diagram that voltage is related to resistance using values. The resistor with the highest resistance value has the highest voltage value, and vice versa. Also, the voltage across the resistors adds to the voltage across the cell. There is an explanatory text for the diagram that supports a conceptual understanding of the key concepts.

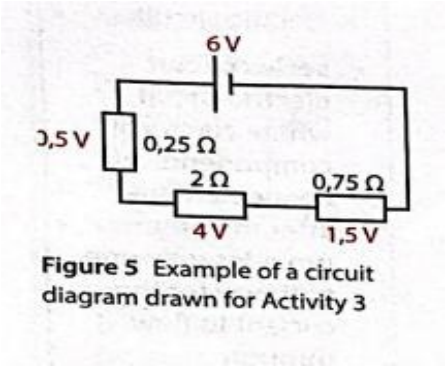



**Figure 4.2: Textbook A diagram of voltage across resistors in series**

In terms of analogies, the textbook uses the analogy of going up the stairs inside a house to explain the concept of voltage across resistors in parallel circuits by relating it to the gravitational potential energy as one goes up the stairs. It is stated that:

*"your difference in potential energy is the same, regardless of which staircase you take. This is almost like the potential difference over resistors in parallel"*

The use of the concept of energy in the analogy to explain the voltage across resistors in parallel can support a conceptual understanding of voltage. There are two other analogies used to explain to clarify the relationship between current and resistance for a series circuit. For a series circuit, the textbook uses a water and hose pipe analogy to explain the relationship. It states that as one makes more knots in the hose pipe then the water that flows in the hose pipe will be less. This is similar to adding more resistors in a series circuit, where the current that flows will be less as more resistors are added because the resistance increases. For parallel circuits, a supermarket till analogy is used. The textbook states that if many customers are using one till and more tills open, the customers can use the other tills. This is similar to adding resistors in parallel, there will be more pathways for current to flow and the resistance will decrease. According to the revealed PCK rubric, the textbook reveals *developing* PCK, because of using at least two representations to present key concepts, where those representations have explanatory texts and discussions.

In addition to circuit diagrams and analogies, the textbook provides instructions for doing demonstrations when presenting voltage across cells in series and parallel circuit connections in practical investigations. Learners are instructed to observe the brightness of the bulbs as more cells are added, and to give a conclusion on the effect of adding cells in series and parallel. The use of questioning during the practical investigations is insufficient as it does not include questions about all the important concepts such as why the brightness changes to elicit learners' thinking of difficult concepts. Furthermore, there is no discussion or explanatory text about the practical investigations of key concepts. This does not reveal *exemplary* PCK about the component according to the revealed PCK rubric because of not having discussions

or sufficient use of questioning to elicit learners' thinking and develop conceptual understanding.

Regarding conceptual teaching strategies, the textbook relies on a practical investigations approach, explanatory texts, and questioning to represent both key concepts of voltage and current in series and parallel circuits. The investigation activities had explanatory texts as discussed above. The use of questioning was evident in the activities. Although the questions asked concerned important and challenging concepts, the questions were mostly about inferring voltage and current from the voltmeters and ammeters in the circuits without necessarily asking about reasons for stating the values. This is likely to support rote learning as opposed to conceptual understanding as the questions required one to refer back to the facts about the concepts and not state reasons for the values given. As a result, the textbook knowledge about conceptual teaching strategies and representations is allocated *developing* level on the revealed PCK rubric. The use of questioning, strategies, and approaches does not necessarily encourage the conceptual reasoning and critical thinking of the key concepts. The approach of practical investigations and questions in the activities supports rote learning as opposed to conceptual understanding. However, there is adequate use of representations to present the key concepts. The explanatory texts provided for investigation activities are sufficient to explain the fundamental concepts in the circuits.

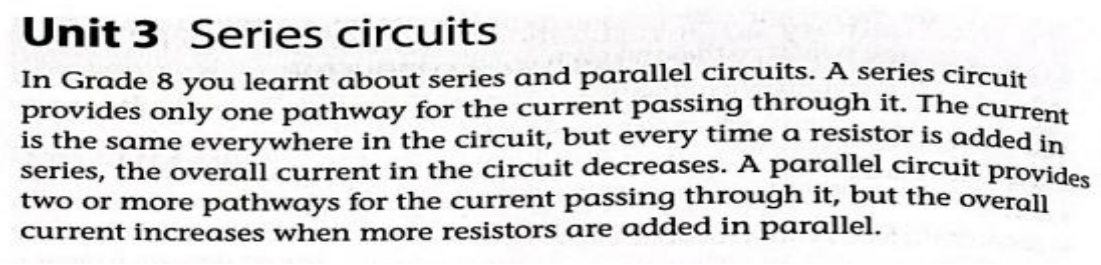
### 4.4 CASE STUDY TWO – TEXTBOOK B

The Department of Basic Education (DoBE) provides textbook B in printed format to all the schools that prefer to use the textbook. The schools are given learners books for all the learners and one teacher's guide. This textbook is not commonly used in the

Sekhukhune East schools. When I was inviting the teachers to participate in the study, I discovered that only one school was using the textbook out of the five schools that I approached. Victoria used Textbook B to prepare and teach the electric circuits topic; hence, the textbook is analysed.

### 4.4.1 Knowledge of curricular saliency

Textbook B authors revise pre-concepts related to electric current (see Figure 4.3 below). Electric current is discussed in terms of differentiating series and parallel circuits, and is related to resistance in series and parallel circuits (Figure 4.3). It is important to differentiate between series and parallel circuits so that learners do not confuse the two circuits.



**Unit 3** Series circuits

In Grade 8 you learnt about series and parallel circuits. A series circuit provides only one pathway for the current passing through it. The current is the same everywhere in the circuit, but every time a resistor is added in series, the overall current in the circuit decreases. A parallel circuit provides two or more pathways for the current passing through it, but the overall current increases when more resistors are added in parallel.

**Figure 4.3: Textbook B pre-concept for current concept**

In addition to the concept of electric current, Textbook B presents the concept of voltage as electrical potential energy. The textbook uses the analogy of relating water pressure to voltage. When presenting the new concepts, the textbook refers to these pre-concepts (see Figure 4.3) and what was learnt in the previous sections. This is evidence for linking new concepts of electrical circuits with the pre-concepts. Compared to the revealed PCK rubric, Textbook B is scored exemplary in terms of the concepts that must be in place before presenting series and parallel circuits and linking those concepts with the new concepts.

The textbook sequences key concepts from voltage to current for resistors connected in series and parallel circuits. This is regarded as logical sequencing in line with the revealed PCK rubric because learners are exposed to the voltage across cells and resistors in series before they learn about the current through resistors in series circuits. The same sequencing is followed for cells and resistors in parallel circuits. This can encourage reasoning about electrical circuits using the concept of voltage instead of current. The interrelatedness of concepts in the textbook is mentioned but it is not explained. As stated in the revealed PCK rubric, the interrelatedness should be explained in order for a textbook to be allocated an *exemplary* level. Since the textbook does not explain the interrelatedness, it cannot be allocated an exemplary level. The interrelatedness of concepts presented in the textbooks are statements from the curriculum. For instance, the textbook states that the current through bulbs connected in a series circuit will decrease as the number of bulbs increases without elaborating or expanding to provide clarity.

In terms of the relevance of concepts in real life, the textbook does not scaffold the concept of voltage or current when it presents the application of electrical circuits at home. It is mentioned that if the filament of a bulb fuses in a series circuit, the other bulbs will not glow, but instead, in parallel the other bulbs will glow. There is no explanation about why the other bulbs will not glow in series circuits while in parallel circuits the other bulbs will glow by referring to the concepts of current. Furthermore, the textbook reveals no relevance regarding the concepts of the next section or grades. The textbook mentions electrical power and fuses, which is about the next section, without referring to voltage and current. According to the revealed PCK rubric, the relevance of textbooks is at the *developing* level.

Regarding the presentation of concepts as prescribed by the curriculum, the textbook omitted the concept of voltage across cells connected in parallel. The textbook presented bulbs connected in parallel circuits in a place of cells in parallel, and bulbs in parallel are part of pre-concepts, rather than new concepts for this Grade. Except for voltage across the cells, the textbook covered all the prescribed concepts by the curriculum. As a result, textbook B's knowledge of curricular saliency is allocated *developing level* on the revealed PCK rubric. In addition to the presentation of concepts by the curriculum, the textbook shows awareness of pre-concepts and it has a logical sequencing from voltage to current. The textbook is not designated as *exemplary* because it does not explain the interrelatedness of concepts and scaffold the concept of voltage and current when presenting the application of electrical circuits in real life.

### 4.4.2 Knowledge of learners understanding of science concepts

Textbook B presents the content of electrical circuits in a way that can prevent emerging learners' challenges and address learners' misconceptions reported in the literature. Learners' misconceptions of current weakening along a series circuit or being shared among components in a series circuit (Sencar & Eryilmaz, 2004) is addressed using a practical investigation. In the practical investigation, the current is measured before the first bulb, between the two bulbs, and after the second bulb. The activity does not require learners to reflect on their observations. Boxes on the sides of the textbook page provide notes or tips (see Figure 4.4 below, for example). The textbook provides a statement about current through resistors in series circuits (see the left side of Figure 4.4 below). According to the revealed PCK rubric, this is considered *basic* because the textbook provides standardized phrases such as "*the current is the same at any point in a given series circuit* (see Figure 4.4 below)*"*, without

providing explanations as to why the current remains the same at any point in a given series circuit. Furthermore, the statements provided by this textbook do not caution learners about the difficulties of the challenging concepts. Caution in this textbook is expected to fall under the boxes of tips or notes on the sides of the pages or emphasis on the key concepts in the statement provided before or after the practical investigation activities.

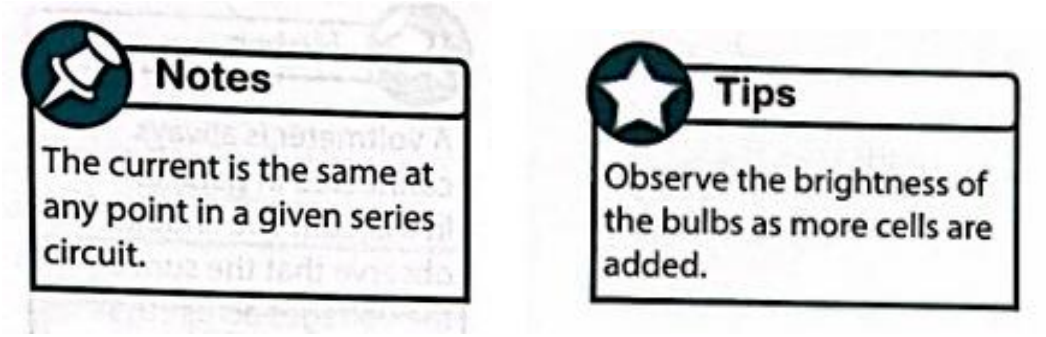



***Figure 4.4: Textbook B representation of concepts***

A schematic circuit diagram for voltage across resistors in series circuits shows arrows that indicate the direction of conventional current. This can prevent learners' misconception that two currents flow from both positive and negative terminals of the battery, viz. the clashing current model (Sencar & Eryilmaz, 2004). Although the current is presented in a way that can prevent learners' misconception of the clashing current model, the textbook does not present any statement about the conventional current, only the diagram. A statement about the conventional current that includes the flow of electrons has the potential to caution learners about the clashing current model. Furthermore, no explanations addresses learners' understanding of this misconception or any other misconception reported in the literature. The statements provided in this textbook reveal a narrow understanding of learners' misconceptions.

Consequently, Textbook B's knowledge of learners' understanding of electrical concepts is allocated at the *basic* level in the revealed PCK rubric. The *basic* level is also based on the fact that this textbook uses standardised phases (see left of Figure 4.4 above), where no explanations or questions are evident to elicit learners thinking of challenging concepts.

### 4.4.3 Knowledge of conceptual teaching strategies including representations

The representations evident in the textbook are schematic circuit diagrams (see Figure 4.5 below). The circuit diagrams are presented alongside practical investigation activities. In some practical investigation activities, learners are required to draw circuit diagrams given a picture of the circuit on a circuit board. In Figure 4.5 below, the circuit diagram is given to guide learners about how to connect resistors in a parallel circuit to measure current at different points using an ammeter. The diagram is suitable to explain current in a parallel circuit. It can even be adapted to explain the current flow in a series circuit. However, there is no explanatory text or discussion about the diagram that can guide the teacher on how to use the diagram to explain the flow of current. This is regarded as *basic* according to the revealed PCK rubric because the textbook is not educative to teachers despite the fact that the diagram is suitable to explain the concept of current.

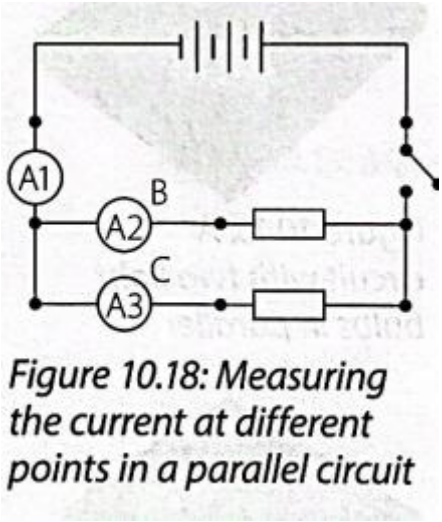



***Figure 4.5: Textbook B representation***

Besides the use of circuit diagrams, the textbook provides instructions for conducting demonstrations to present voltage across cells connected in series circuits and for the relationship between resistance and current in parallel circuits. For voltage across the cells, learners are instructed to observe the brightness of the bulb as cells are removed or added to the circuit, while for the relationship between resistance and current, learners are instructed to observe the brightness of bulbs as more bulbs are added in parallel. Similar to the use of circuit diagrams, there is no explanatory text or discussion about the demonstrations suggested by the textbooks that can support the teacher in facilitating cognitive discussions of the fundamental concepts.

Regarding conceptual teaching strategies, no explanations or questions support the conceptual development of voltage, current, and resistance in textbook activities or discussions. As explained in section 4.4.1, under the knowledge of curricular saliency, the textbook provides statements as these emerge from the curriculum document. There are seldom questions about the key concepts. The questions are basic in the activities at the end of the topic. The teaching strategy suggested uses practical

investigations to present voltage and current for resistors in series and parallel circuits. Learners are instructed to infer voltage from voltmeter readings and current from ammeter readings. The investigation activities are more about the verification of electrical circuit concepts with no questions or explanatory texts to develop conceptual reasoning and critical thinking. Hence, it is concluded that the textbook supports rote learning. This is further supported by the statements provided alongside the investigation activities (see knowledge learners' understanding of the science concepts component in Figure 4.4.2). Consequently, Textbook B's knowledge on this component is allocated a *basic* level on the revealed PCK rubric. Although there are circuit diagrams and instructions on how to conduct demonstrations to present key concepts, there are no explanatory texts or discussions that can support teachers' use of the representations.

## 4.5 CASE STUDY THREE: TEXTBOOK C

Textbook C is an electronic textbook approved by the Department of Basic Education (DoBE) because it presents the curriculum's prescribed content. It is free of charge, and teachers can download it online. Natural Sciences curriculum advisors share Textbook C on official WhatsApp groups for Natural Science teachers in Sekhukhune East District. Upon request, the DoBE provides the textbook in print format to the schools. Robben used textbook C when preparing to teach electric circuits; hence, the textbook receives analysis herein.

### 4.5.1 Knowledge of curricular saliency

Textbook C reveals an awareness of the pre-concepts by discussing the pre-concepts before presenting new concepts. For instance, voltage is discussed before presenting voltage across cells in series circuits. The discussion includes the meaning of voltage,

the connection of the voltmeter, and the rationale for connecting the voltmeter in parallel. Although the concept of current is not discussed, the textbook provides questions that can be used to facilitate discussion about current. Furthermore, the textbook revises the relationship between current and resistance using practical investigation activity before presenting voltage and current for resistors in series and parallel connection. It can be inferred that new concepts are linked with corresponding pre-concepts. In line with the revealed PCK rubric, this textbook reveals exemplary PCK for awareness of pre-concepts, making it easy to link them with new concepts.

Regarding the sequencing of key concepts, textbook C does not follow the same sequencing for voltage, current, and resistance when presenting resistors in series and parallel circuits. The voltage across resistors in series is presented, followed by the current through the resistors, while for resistors in parallel circuits, the current through resistors is presented, followed by the voltage across the resistors. This can have implications for the cause and effect of electrical circuit concepts. It is necessary to make the cause and effect of electrical circuit concepts explicit for conceptual development. Regarding interrelatedness of the concepts, textbook C explains the interrelatedness of the concepts of voltage, current and resistance. The evidence supporting this is that, when voltage is related to current for cells in series and parallel circuits using practical investigations whereby learners should infer the relationship of voltage and current from voltmeter and ammeter readings. Furthermore, using practical investigations, the current is related to resistance for resistors in series and parallel circuits. In addition to using practical investigations for the interrelatedness of voltage and resistance for resistors in a series circuit, the textbook discusses the relationship of the concepts with examples and the use of a diagram. According to the

revealed PCK rubric, textbook C reveals *exemplary* PCK because it explains the interrelatedness of the key concepts.

The textbook reveals the relevance of concepts for real-life applications that scaffold towards concepts of voltage and current, as stated in the revealed PCK rubric. The textbook uses lightning systems as an example to present the application of electrical circuits at homes. This is done through the use of practical investigation, where learners are instructed to connect two bulbs in series and in another circuit two bulbs in parallel, and to then disconnect one bulb to determine whether the other bulb will continue to glow. The activity is not discussed. However, questions of the activity scaffold the concept of current. Additionally, an example is provided where it is stated that if bulbs are connected in parallel circuits and the filament of one bulb burns fuses, then the other bulb will continue to glow. The relevance of concepts is also revealed regarding concepts to be learnt in the next grades. This is evident when the textbook briefly introduces Ohm law as an extension (see Figure 4.6 below). The curriculum prescribes Ohm's law for higher grades. The textbook authors seem to be aware of this because they stated the law as an extension. The textbook briefly discusses the relationship between resistance, voltage and current, and then presents this as a formula (see Figure 4.6). This is followed by an example of calculations that support the relationship of the three concepts by relating the values.

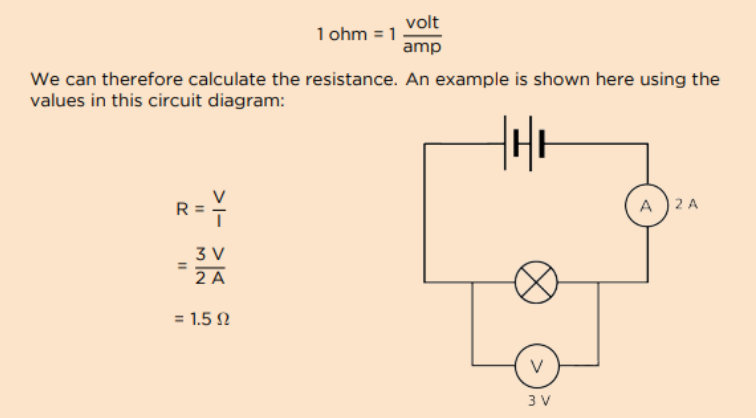



**Figure 4.6: Relevance of textbook C**

Textbook C's knowledge of curricular saliency is allocated an *exemplary* level on the revealed PCK rubric. This is based on presenting all the prescribed concepts by the curriculum and the above discussion. The textbook revealed awareness of pre-concepts, explained how electric circuit concepts are related and the relevance of concepts in terms of application scaffold concept of current. Even though the sequencing changed from voltage to current for resistors in series and parallel circuits, the interrelatedness is explained and can prevent difficulties that may arise due to the sequencing change.

### 4.5.2 Knowledge of learners understanding of science concepts

The textbook presents challenging concepts in such a way that can address and prevent learners' misconceptions and difficulties of electrical circuit concepts. For instance, there is explanatory text about the voltage across cells in parallel circuits that can address learners' difficulty with the superposition model. The superposition model is when learners believe that the physical arrangements of cells do not affect the overall voltage across the cells (Engelhardt & Beichner, 2004). The textbook provides explanatory texts stating that the overall voltage across two cells in parallel connection will be the same as that of an individual cell. Furthermore, the textbook states that

adding more cells in a series increases voltage and current strength. In addition to the explanatory texts evident in textbooks, there are practical investigation activities about the voltage across cells in electrical circuits that can address any challenge learners have about superposition model misconception. In line with the revealed PCK rubric, this is regarded as *a developing* level*,* given that there are explanatory texts and practical investigation activities that can address learners' challenges of the superposition model.

In the investigation activities mentioned above, the textbook authors referred learners to voltage and current without explicitly explaining the cause and effect. Including explanatory texts about voltage and current can possibly address learners' difficulty with these two concepts. Literature shows that learners use the concepts interchangeably and struggle to understand voltage as the cause of current, not the other way around (Engelhardt & Beichner, 2004). Learners believe that adding resistors in parallel circuits increases the total resistance of the circuit (Sencar & Eryilmaz, 2004). There is explanatory text about parallel circuit misconceptions that can address learners' misconceptions. The explanatory text (see Figure 4.7 below) clearly states that adding resistors in parallel circuits decreases the total resistance in the circuits. Furthermore, the textbook relates the total resistance with the total current in the circuit. After the explanatory text, an analogy explains the relationship between current and resistance in a parallel circuit in order to clarify the relationship between resistance and current in a parallel circuit. According to the revealed PCK rubric, the textbook reveals *developing* PCK for the parallel misconception.

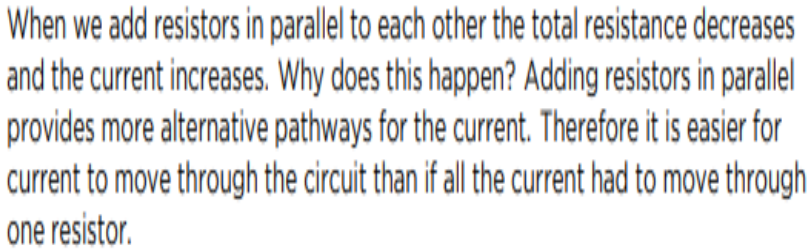



**Figure 4.7: Textbook C learners' understanding of science concepts**

Although the textbook reveals adequate knowledge of learners' understanding of the parallel and superposition model, as discussed above, it reveals a narrow understanding of some of the misconceptions and challenges discussed in section 2.4.1 under Chapter 2. This is because the textbook does not have statements or explanatory texts that caution learners about some of the common misconceptions and challenges. For this textbook, caution is expected to be in the boxes on the sides of the textbook pages (see Figure 4.8 below). The box of take notes cautions learners about confusing the words cell and battery, which is not regarded as a misconception because it can easily be rectified. No misconceptions or challenges are evident in the "take note" and "did you know" boxes. Furthermore, there are no statements or explanatory texts, such as the ones provided in Figure 4.7 above for common and persistent misconceptions, such as learners' understanding of electric current through resistors in a series circuit.

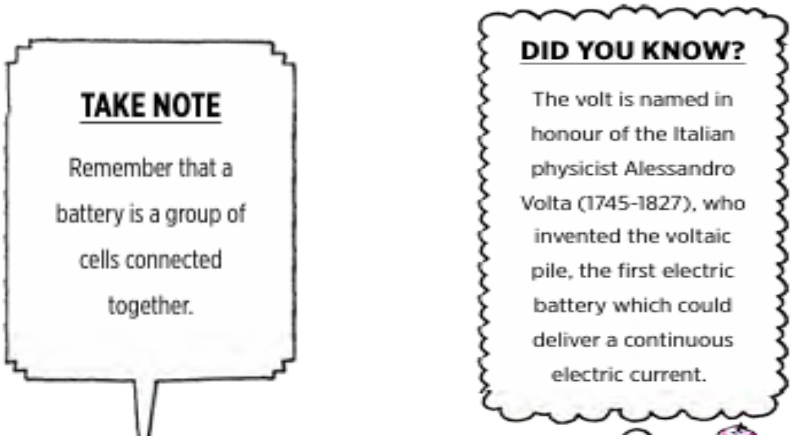



***Figure 4.8: Textbook C learners' understanding of science concepts***

The textbook has provided an explanation that states that, “current is inversely proportional to the resistance to explain the relationship between current and resistance in a series circuit”. This explanation can enforce misconception, because it means that a change in current will affect resistance, which is in fact not the case. Instead, it is the change in resistance that affects the flow of current, not the other way around. For this reason, this textbook's knowledge of learners' understanding of electrical circuit concepts is allocated at the *basic* level in the revealed PCK rubric because it contains explanations that may enforce misconceptions, while failing to caution learners about some common misconceptions.

### 4.5.3 Knowledge of conceptual teaching strategies and representations

Circuit diagrams, analogies, and videos are the representations used in textbook C to present electrical concepts. Circuit diagrams are available in schematic format, where circuit symbols are used, and in picture format, where real pictures of electrical components are used to illustrate circuit diagrams. The diagrams are used in activities and discussions (see Figure 4.8 below). The textbook provides links to videos about electrical circuits, key concepts of circuits, and water and hose pipe analogy. However,

when I tried to access the videos or simulations using the links provided, none of these worked. This can present a disadvantage if the teacher tries to use the links provided. Regarding analogies, the textbook explains the flow of current in parallel circuits using analogy. It is stated that if learners use one door to exit the classroom, it will take a while, but if the number of doors increases, more learners will leave the classroom simultaneously. This is similar to current flow in a parallel circuit, where, as more resistors are added, the flow of current through the resistors increases.

In addition to using circuit diagram representations and analogies and providing video links, textbook C provides instructions on conducting demonstrations and computer simulations. Demonstrations are evident in practical investigation activities to present voltage across cells in electrical circuits and the relationship between resistance and current. In both cases, learners are referred to the brightness of the bulbs in order to infer voltage across cells and the relationship of resistance and current in electrical circuits. In terms of computer simulations, the textbook provides instructions on how to conduct investigation activity for voltage across cells connected in series. In line with the revealed PCK rubric, the textbook reveals *exemplary* PCK due to the extensive use of representation to teach key concepts of electric circuits.

Regarding conceptual teaching strategies, Textbook C uses practical investigation activities, discussions, and questions in order to present the fundamental concepts. The investigation activities are used to present voltage and current for electrical circuits. Learners are required to infer voltage across resistors from the voltmeter readings, and current through the resistors through ammeter readings. This is followed by interpreting the results, where the textbook questions scaffold the concept of voltage and current. The investigation activities start with a hypothesis or investigation

questions and end with a conclusion. In addition, most investigation activities included circuit diagrams as a guide on connecting the components and the method provided. The use of questioning is evident in discussions, investigation activities and activities. Some of the questions include:

- *What happened to the brightness of the bulbs and the ammeter reading as more light bulbs were added to the circuit? Explain your observations*
- *What do you notice about the readings on $V_2$ and $V_3$ when compared to $V_1$?* [to explain voltage across resistors in series]
- *Add the readings on $A_2$ and $A_3$ together. What do you notice?* [to explain current through resistors in a parallel]
- *Why did the light bulb in the parallel circuit keep shining after you removed the other bulb?* [relevance of concepts in terms of application of electrical circuits]

The use of questions reveals the *developing* PCK because the questions support the conceptual development of the key concepts of electrical circuits.

Besides using questions, discussions and explanations are provided for some key concepts. For example, the voltage across cells in parallel circuits and the voltage across resistors in series circuits are discussed. For the discussion of voltage across resistors in series circuits, the discussion includes the relationship between voltage and resistance. The explanation provided in the discussion can enhance the conceptual development of voltage because voltage is related to energy. Furthermore, there is the use of a circuit diagram to emphasise the fact that the voltage across the resistors in a series circuit is the same as the voltage across the battery (see Figure 4.9 below).

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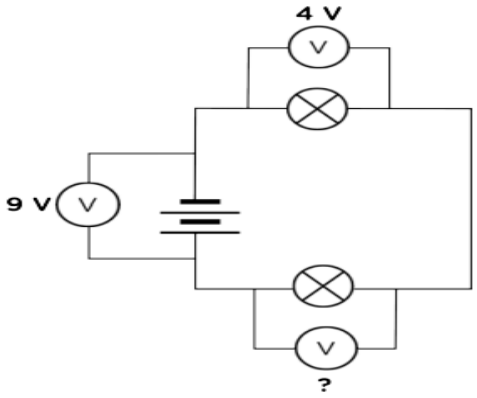


If the potential difference across the cells or battery is 9 V and the potential difference across one of the bulbs is 4 V, what would the reading on the third voltmeter be?

**Figure 4.9: Textbook C representation**

In line with the revealed PCK rubric, textbook C knowledge and competence of conceptual teaching strategies including representations, is allocated *developing* level. This is based on the extensive use of representation to explain key concepts of electrical circuits. Furthermore, there are investigation activities using questioning and circuit diagrams. In contrast to the revealed PCK rubric, there are seldom explanatory texts for practical investigations, and a discussion of some challenging and important concepts, such as the flow of electric current in series circuits. For this reason, Textbook C is not allocated an *exemplary* level.

## 4.6 CONCLUSION

This chapter presented the content analysis of three Natural Sciences textbooks to reveal the PCK presented in textbooks regarding components of PCK. The PCK rubric was utilised to determine the quality of PCK per component as revealed in textbooks using the levels of limited (lowest level), basic, developing, and exemplary (highest

level) (see Appendix II). The results for three textbooks are presented in Table 4.2 below per component.

***Table 4.2: Summary of textbook scores on PCK components***

| **Textbooks** | **Curricular saliency** | **Learners understanding of science concepts** | **Conceptual teaching strategies and representations** |
|---|---|---|---|
| **Textbook A** | *Exemplary* | *Basic* | *Developing* |
| **Textbook B** | *Developing* | *Basic* | *Basic* |
| **Textbook C** | *Exemplary* | *Basic* | *Developing* |

Table 4.2 above reveals that the PCK revealed in textbooks varied across its components. The three textbooks often presented content the same way, using practical investigation and providing instructions for demonstrations. Furthermore, the three textbooks are representations of the curriculum, as the table shows that they are rated at developing or exemplary levels for knowledge of curricular saliency. The three textbooks were used by the four teachers who took part in this research namely Nkatego, Victoria, Robben and Steve, to prepare and teach electric circuit topic. Nkatego, Robben and Steve used Textbook A, while Victoria used Textbook B. Besides using Textbook A, Robben used Textbook C when preparing for the lesson. The next chapter presents a content analysis of how the four teachers used textbooks when preparing and teaching electric circuits to their learners in their respective classrooms.

# CHAPTER 5: TEACHERS ENACTED PCK

## 5.1 INTRODUCTION

In this chapter, I present and analyse data that reflect manifestations of teachers' enacted PCK (ePCK). This chapter builds upon the previous chapter, which analysed the educative nature of textbooks. In this instance, focus is placed on how teachers teach electric circuits and how the PCK revealed in Natural Sciences textbooks impacts teachers' ePCK. Data sources were classroom observations and interviews. Interviews were divided into semi-structured and video-stimulated recall (VSR) interviews to capture teachers' ePCK about planning and reflection on the lesson. I first discuss an overview of the analysis of teachers' ePCK. An analysis of teachers' ePCK follows, presented as a case study for each teacher, and the way in which the teachers used the textbooks. I then provide an overview of the quality of teachers' ePCK and PCK revealed in textbooks in a table format along with a brief discussion. The conclusion of the chapter follows on this.

## 5.2 AN OVERVIEW OF THE ANALYSIS OF ENACTED TEACHERS' PCK

Teachers' ePCK was analysed using PCK components proposed in the grand PCK rubric as themes for content analysis, as presented in Appendix II. The components are knowledge of (i*) the curricular saliency of the topic; (ii) learners' understanding of science concepts; and (iii) conceptual teaching strategies, including representations*. Evidence that reflects teachers' manifestations in each PCK component is discussed in Table 5.1 below, which gives an overview of the major aspects that I searched for when analysing teachers' ePCK data. Furthermore, the ePCK rubric was used to evaluate teachers' competence on a four-point scale of *limited, basic, developing, and*

*exemplary* for each PCK component. See section 3.7 of Chapter 3 for more details about the rubric. In order to analyse the content of electric circuits for Grade Nine, I was guided by the Curriculum Assessment and Policy Statement (CAPS) document which prescribe three key concepts of voltage, current and resistance for cells and resistors connected series and parallel. The analyses was not done at concept level by focusing on one concept at a time, it was done at topic level focusing on all the concepts within the topic.

***Table 5.1: Example of evidence of PCK components***

| **PCK component** | **Example of evidence** |
|---|---|
| Curricular saliency | • Knowledge of pre-concepts that need to be in place<br>• New concepts are developed or linked with the corresponding pre-concepts<br>• The sequencing and interrelatedness of the concepts<br>• The relevance of concepts in terms of real-life application and future concepts scaffold towards conceptual understanding<br>• Presentation of the prescribed concepts by the curriculum |
| Learners understanding of science concepts | • Teachers' awareness of learners' misconceptions and learners' difficulties in electric circuits<br>• Addressing learners' difficulties reported in the literature and emerging learners' difficulties<br>• The facilitations of discussions that uncover learners understanding of difficult concepts |
| Conceptual teaching strategies including representations | • The use of representations such as demonstrations, models, diagrams, and analogies to present important and difficult concepts<br>• The use of teaching strategies that support conceptual understanding of key concepts and does not encourage rote learning and algorithm |

| | |
|---|---|
| | • The use of questioning to encourage conceptual reasoning |

I conducted classroom observations before conducting the interviews, because I did not want the participating teachers to use interview questions to plan the lessons. After classroom observations, I conducted semi-structured interviews first, and then clarified that the questions involved planning the lesson before going to the classroom. A video-stimulated recall (VSR) interview was conducted immediately after the semi-structured interviews in order to ask teachers questions that probed them to reflect on specific sections of their lessons.

Classroom observations were video recorded, and data was divided into sections such as revising learners' prior knowledge, teaching key ideas, and consolidating the lesson. The sections were then narrated and coded using PCK components (see Table 5.1 on the previous page for evidence that reflects PCK components and the ePCK rubric in Appendix II). Interviews were audio-recorded, and data was transcribed and coded, similar to classroom observation data. After coding, I conducted in-depth content analysis for four Natural Sciences teachers, looking for evidence that reflects teachers' enactment of the collective PCK presented in textbooks in their practice. I remembered that even though the teachers used textbooks in planning or teaching, their PCK did not necessarily result only from the textbook. I looked for data that revealed rich ePCK when teachers were using textbooks.

## 5.3 CASE STUDY ONE – NKATEGO

Nkatego was teaching the topic of electric circuits for the first time. She did undergraduate Physics II for her BSc degree; therefore, it can be assumed that she had adequate content knowledge to teach the electric circuits. The school was poorly resourced. She used Textbook A and study material that she got from official

WhatsApp group of Natural Sciences provided by Curriculum Advisor as resources for teaching electric circuits. Learners were given pamphlets that had the same notes as the study material at the beginning of the lesson. She was observed teaching resistors in series and parallel circuits in one lesson of 60 minutes. Her lesson was divided into sections as shown below.

**Section 1:** Revision of prior knowledge [Time 06mins 30s]

**Section 2:** Teaching resistors in series and parallel circuits [Time 10mins 27s]

**Section 3:** Application of resistors in a parallel circuit [Time 13mins 22s]

**Section 4:** Application of resistors in a series circuit [Time 11mins 18s]

**Section 5:** Consolidation of the lesson [Time 2mins 32s]

### 5.4.1 Nkatego PCK and practice

**a) Knowledge about curricular saliency of the topic.**

Nkatego started the lesson by revising pre-concepts of resistance, factors that affect resistance and Ohm's law as covered in the previous lessons. She briefly explained resistance and wrote down R=V/I on the board but did not state Ohm's law in words. Textbook A covers all the pre-concepts she revised in the previous topic except for Ohm's law. Nkatego developed or linked some new concepts with pre-concepts. When teaching current for resistors in a circuit, she referred learners to the pre-concept of a series of circuits with one pathway for current to flow, while parallel circuits with two or more pathways for current flow. This is the same way that textbook A presented the concept. Although Nkatego referred to current when teaching resistors in series and parallel connection, she did not refer to the key concept of voltage when teaching

voltage across resistors in series and parallel connection. She only mentioned the connection of cells, stating that cells can also be in series or parallel without mentioning the voltage across the cells. This differs from how Textbook A presented the concept of voltage across resistors in circuits. In Textbook A, voltage is briefly revised before presenting it across the cells and resistors. In line with the ePCK rubric, Nkatego's knowledge of pre-concepts and linking new concepts with pre-concepts was observed to be *basic*. This is because she revised the key concept of current only. She did not briefly revise the key concept of voltage and link resistors with resistance, as covered in the previous lesson.

The sequence of key concepts during Nkatego lesson was from current to voltage for resistors in circuits. This is different from textbook A sequencing. Textbook A sequence key concepts from voltage to current for both circuits. When Nkatego was asked about her sequencing of current and voltage during the VSR interview, she stated:

*"Like I said, every time I tell them [learners] to show the current direction. If they start by showing the current direction, then they will identify whether resistors are in a series or parallel connection. If the current is the same, they are in series and if it is divided, they are in parallel connection."*

The reason for starting with current instead of voltage was to identify the type of circuit, whether it is a series or parallel circuit. Although the sequencing of current to voltage can help learners to identify the type of circuit, it may in turn lead to learners reasoning about voltage as a property or consequence of current. As for the interrelatedness of the concepts, Nkatego related the key concept of resistance to the current to explain the relationship for resistors in a parallel circuit. She did not relate current with

resistance for series circuits. She also did not relate resistance with voltage for resistors in series circuits. On the other hand, Textbook A relates current with resistance and voltage with resistance for resistors in series circuits. Furthermore, the textbook relates voltage with energy in brief, but does not relate voltage with current. Nkatego's knowledge of the interrelatedness of the key concepts is *basic* according to the ePCK rubric. She did not relate voltage to resistance, current, or energy.

Nkatego taught the key concepts of current and voltage for resistors in both series and parallel circuits. She stated that the current that passes through resistor one will be the same current that passes through resistor two for resistors in series. For resistors in parallel, she explained that the current will split when it gets to a branch and re-joins, then return to the battery. For voltage, she stated that voltage is split between resistors in series, noting that it is the same across resistors in parallel. The textbook also covered all the key concepts that Nkatego covered. In terms of the relevance of learning about electrical circuit concepts, Nkatego did not relate the content of electric circuit concepts to learners' everyday lives. Textbook A relates electrical circuits to learners' everyday lives in a way that scaffolds the concept of current. For the relevance of electrical circuit concepts in relation to future concepts, Nkatego did calculations using the formula of R=V/I to determine the voltage across resistors in circuits and the resistance of the resistors. Textbook A does not include any of these calculations. In the curriculum statement, the calculations are stated for the next grade. In line with the ePCK rubric, Nkatego's knowledge of presenting content prescribed by the curriculum and the relevance of future concepts is allocated to the *developing* level.

Overall, Nkatego's competence and knowledge about curricular saliency is allocated *to the developing* level on the ePCK rubric. This is because she discussed all the concepts prescribed by the curriculum, the sequencing of key concepts scaffold toward the conceptual understanding of the current, and the relevance of concepts were related to what is going to be learnt in the next grade. However, Nkatego did not explain the interrelatedness of most concepts or link most new concepts to pre-concepts. As discussed, the key concept of voltage was not developed or linked to corresponding pre-concepts. Furthermore, voltage was not related to energy, current and resistance. In the previous chapter, Textbook A was allocated *exemplary* PCK, a level higher than Nkatego's knowledge of curricular saliency.

**b) Knowledge about learners' understanding of science concepts**

In the interview, Nkatego related learners' difficulties and misconceptions with her PCK by saying that, if learners do not understand a concept, this means she was not able to explain it clearly. When asked about learners' difficulties or misconceptions about Grade Nine electric circuits, Nkatego mentioned the application of resistance, the relationship between resistance and current, the application of series and parallel circuits and manipulating R=V/I for calculation purposes. However, only the relationship between current and resistance is reported as a misconception in the literature as a local sequencing model misconception (Sencar & Eryilmaz, 2004). The application of series and parallel circuits is reported as a challenge for learners in the diagnostic reports. Learners have challenges when it comes to identifying resistors connected in series and parallel circuits (Department of Basic Education, 2023). In line with the ePCK rubric, Nkatego reveals *basic* PCK because of mentioning one misconception and challenge reported in the literature.

Nkatego addressed learners' difficulty of the way in which current is related to resistance in parallel circuits by using a schematic circuit diagram from Textbook A (see Figure 5.1 (left) below) and providing explanations. She explained that current does not divide equally for resistors in parallel circuits. Rather, the way in which the current divide depends on the resistance of the resistors in each branch, this was evident when she changed the resistance of one of the resistors from one ohm to two ohms in the diagram. She then explained that unlike before, where current was divided equally (2A each) because of equal resistance of the resistors, now more current will flow through the one-ohm resistor and less current will flow through the two-ohm resistor. This is similar to the way in which Textbook A presented the interrelatedness of current and resistance, by asking which ammeter would have high resistance where the current through each resistor in the branch was different (see figure 5.1 below, the right side). Additionally, the textbook used the analogy of tills in the supermarket to explain the interrelatedness of current and resistance. Nkatego was observed using only the diagram, and no analogy was used.

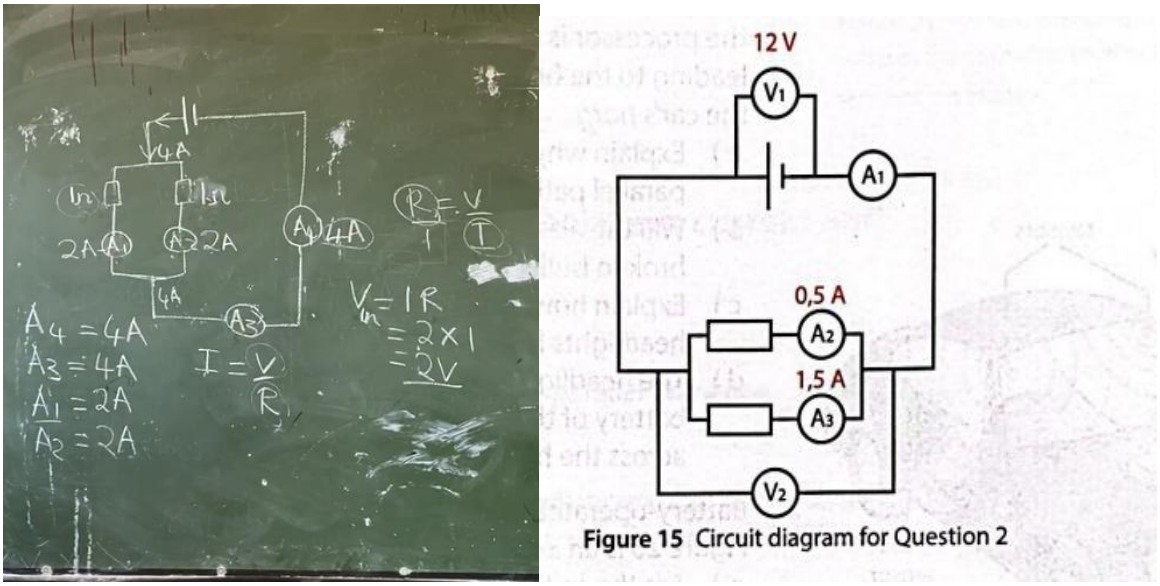


***Figure 5.1: Nkatego (left) and textbook (right) representation***

When Nkatego was redrawing the circuit diagrams from Textbook A, she added arrows to show that the flow of current is from the positive to the negative terminal of the cell. This can prevent learners' misconception of believing that current flows from both positive and negative terminals of the battery (Aligo et al., 2021). However, it cannot be inferred that she is aware of the misconception because she did not discuss conventional current during the lesson, and she did not list this as a misconception during the interview.

During the VSR interview, Nkatego noted the main reason for changing the resistance of one resistor was to show learners that resistance is inversely proportional to current. I think she is reinforcing a misconception because this implies that current can be the independent variable and resistance the dependent variable. Although it is true that an increase in the resistance of the resistor decreases the current through the resistor, it is not true that an increase in current in the circuit will decrease the resistance of the resistor. Resistance is a property of the resistor and not determined by current.

The statement that "*resistance is inversely proportional to current*" stems from the way in which she interprets the formula R=V/I (see Figure 5.2 below). From a mathematics perspective, the formula R=V/I means that an increase in R leads to a decrease in I and vice versa. However, this is not true from a scientific perspective because a change in current cannot affect the resistance of resistors. The misinterpretation of the formula of R=V/I is reported to be the cause of electric circuit misconceptions in the literature (Aisahsari & Ermawati, 2020). Because Nkatego used the statement that misinterprets the formula throughout the lesson, learners might develop misconceptions about the key concepts of resistance and current, even though this was not the intention of the teacher. In textbook A, the statement is not presented.

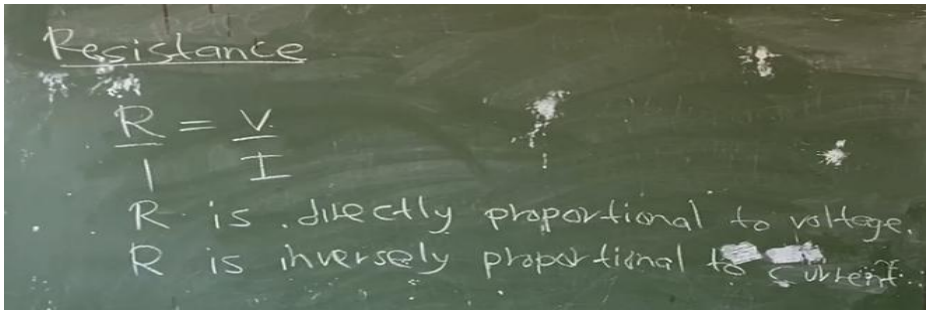


***Figure 5.2: Nkatego interpretation of Ohms law formula***

Overall, Nkatego's knowledge of learners' understanding of science concepts is allocated *basic* on the ePCK rubric. This is based on mentioning one misconception reported in the literature. Furthermore, she addressed the misconception using diagrams and questions from Textbook A, while providing her own explanations. She did not reveal *limited* PCK because she did not present misconceptions to learners which was going to reveal no understanding of learners understanding of electrical circuit concepts. She did not reveal *developing or exemplary* PCK of this component because she did not mention well-known and persistent misconceptions reported in the literature during the interview. In addition, she presented the concepts in a way that can prevent and address some learners' challenges by providing standardised phrases such as current is the same through resistors in series circuits. Also, the way in which she presented some content could enforce a misconception, as discussed in the above paragraph.

**c) Conceptual teaching strategies and representations.**

Nkatego used schematic circuit diagrams from Textbook A as representations to teach the key concepts of voltage and current for resistors in circuits. Different from Textbook A, she used mathematical equations to supplement the circuit diagrams. In Figure 5.3 below, the right side shows the circuit diagram she drew, exactly like the one in

textbook A, and the left side shows the equations from other materials, not textbook A. The diagram was used to explain the current flow for resistors in series circuits, and that voltage across the resistors in series adds up to the voltage of the battery. The equations of $A_1=A_2$ and $V_1=V_2+V_3$ were used to determine the current through resistors and voltage of the battery, guided by the textbook questions (see Figure 5.3 below). In addition to determining the values of voltage and current, Nkatego determined the resistance of the resistors using the formula of R=V/I (see Figure 5.3 below). The textbook did not present any questions about determining the resistance of resistors. In the textbook, learners were given values of resistance in other examples. The values of resistance were then related to the values of voltage to supplement the explanation for the interrelatedness of voltage and resistance. This was not the case with Nkatego. She determined the values of resistance of resistors and moved on to teach other concepts. It can be assumed that the use of mathematical equations served to encourage rote learning rather than conceptual understanding.

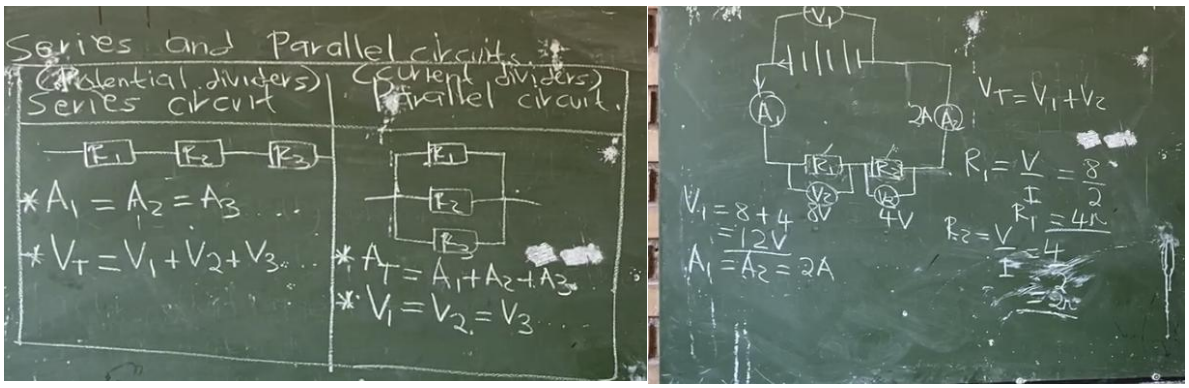


**Figure 5.3: Representations used by Nkatego**

Apart from using circuit diagrams, textbook A uses analogies and provides instructions for demonstrations to represent electrical circuit concepts. Nkatego only used the circuit diagrams. For this reason, Nkatego's knowledge of representations reveals

*basic* PCK according to the ePCK rubric because she did not use multiple representations to teach electrical circuit concepts.

Regarding conceptual teaching strategies, Nkatego used the lecture method and questioning method, and providing explanations for the key concepts of circuits throughout the lesson. She started by asking low-order and leading questions in the first two sections. As she asked questions, she expected learners to recall the principles of series and parallel circuits. Some of the answers were correct, while others were incomplete, as follows:

*Nkatego: How is the voltage calculated in a series circuit?*

*Learner: The voltage is split between the resistors.*

Nkatego acknowledged the learners' answers as correct and represented the statement as an equation (see Figure 5.3 above). Although the voltage is indeed split across the resistors, the learner did not relate the voltage across the resistors with the voltage across the battery. Nkatego did not expand the learners' answer by explaining that the sum of the voltage split across the resistors is equal to the total voltage across the cell/battery and that the voltage across the resistors depends on the resistance of the resistors. Also, she did not engage the learners by asking them to expand on their answers or questioning their answers. Instead, she would take the answer, even if it was not entirely correct, and represent it in an equation without any discussion. Textbook A provided a full statement for voltage in a series circuit and related voltage across resistors with resistance in words and using a circuit diagram. In some instances, Nkatego rephrased the question if learners' answers were not entirely correct, but still, there was no discussion or expanding learners' answers.

In sections 3 and 4, Nkatego used a similar approach as sections 1 and 2, drawing from circuit diagrams used in Textbook A and providing explanations. She did calculations for the concept of voltage for series and parallel circuits without providing any explanations. The explanations were provided for the concept of current only while using the diagrams and adding to learners' answers. Learners were engaged in a discussion about the first thing to do when answering questions about circuits. Learners' ideas about what to do first were not initially clear. Nkatego then used questions to guide learners to determine what is the first thing to do. Once learners figured it out, she explained how they must identify the type of circuits by the flow current. Although there was a discussion, the discussion was not about the key concepts of voltage, current and resistance. The textbook she used had discussions and explanatory texts about the concepts of voltage and current for circuits.

During the semi-structured interview, Nkatego mentioned demonstrations as an effective teaching strategy for teaching electric circuits. If it was up to her, she would start the lesson with demonstrations, move to theory and examples, then draw the diagrams and have discussions and calculations accordingly. The textbook she was using had instructions for demonstrations. She said she could not do the demonstrations due to the size of the class and lack of appropriate resources. She further noted that if she were to do demonstrations, she would follow the instructions for demonstrations suggested by Textbook A. The demonstrations were not related to any concept or how they would help learners grasp key concepts. The idea of demonstration was suggested because the teacher reasoned that if learners see the type of circuits, the visualization will aid their conceptual understanding.

Nkatego's reflection during the VSR interview suggests that she encourages rote learning as opposed to conceptual understanding. When asked why she did not talk about voltage when she was teaching resistance and current, she responded as follows:

*"The reason why maybe I did not touch too much on voltage is that I already told them that when the resistors are connected in parallel their voltage will be the same, and when the resistors are in series, the voltage will be different"*

Here, she is encouraging learners to memorise that voltage is divided or the same depending on the type of circuits without explaining why this is the case, which would develop conceptual reasoning of the key concept. When I asked her how she would include voltage if she were to teach the topic again, she said:

"*I would say that the voltage is directly proportional to resistance. If resistance increases, the voltage will increase, but the current will decrease.*"

From the quotation above, Nkatego still encourages learning of statement of fact without providing explanations for such statements. Furthermore, the statement is inaccurate, because when resistance increases, the current will decrease, provided that voltage is a controlled variable, and when voltage increases, the current will increase, provided resistance is a controlled variable. Nkatego seems to have a limited understanding of the interrelatedness of the three concepts. The textbook did not interrelate the three variables, stating the dependent, independent and controlled variables.

Overall, Nkatego's competence and knowledge about this component is allocated *basic* level on the ePCK rubric. There was adequate use of circuit diagrams as

representations to explain key concepts of current and voltage. As said in the rubric, the *basic* level is allocated if the teacher seldom provides explanations and facilitates discussions for important concepts. This was the case with Nkatego because she did not engage learners, facilitate discussions, or provide sufficient explanations for the concepts of voltage and current in circuits. Furthermore, her strategies encourage rote learning as opposed to conceptual development and change. Textbook A revealed *developing* PCK, a level higher than Nkatego's own knowledge of this component.

### 5.4.2 The use of a textbook by Nkatego

Nkatego's reasons for using Textbook A is that she wants the learners to value the way in which the content is presented in the textbook, and not think of the textbook as lacking efficacy. In her own words, she noted in this regard:

*"For the reasons that learners do not see it as useless, because we give them at the beginning of the year*".

It looks like she values how the content is presented in the textbook; hence, she uses the textbook and encourages the learners to use the textbook, even though she uses other curricular materials. Nkatego went on to say that she uses the textbook to give learners examples. During the lesson, I observed her using the circuit diagrams from the textbook to give examples of circuits. After she presented the theory and summarized it in a table format, she looked for diagrams from the study material and found it to be too straightforward and switched to the textbook. In the interview, she said she uses textbook representations to address learners' difficulties and misconceptions.

***Nkatego:*** *"I use the representations from the textbook because the notes are not having too many examples. The notes are just full of the theory that they need to know and then the application part which now give them examples I will use the textbook as such."*

This suggests that she values the PCK revealed in textbooks and uses that to help learners comprehend the content. In addition to using circuit diagrams from the textbook, she used questions from textbook activities to emphasise the key concepts of voltage and current. I speculate that she used study materials for content knowledge because she observed that, "*the notes are full of theory*". In a casual conversation, when I invited her to participate in the study, she noted she supplemented the textbook with other materials because the content knowledge in the textbook was limited. Surprisingly, the content she presented from the study material is also available in the textbook. Analysis of the textbook in the previous chapter revealed that the textbook can be educative.

## 5.5 CASE STUDY TWO – VICTORIA

Victoria had two years of teaching electric circuits when data was collected. She holds a Bachelor of Arts (BA) degree, with life sciences as a major subject, and did not do any physics module. It can be assumed that she lacks the content knowledge of physics to teach electric circuits, because she did not undertake physics at the undergraduate level, and is not teaching physics at the school. She seemed not confident when she was teaching. The resources she used are textbook C, provided by the school, and the study guide from the official district WhatsApp group of Natural Sciences teachers. The school was poorly resourced. I observed her teaching the whole topic in one lesson of 60 minutes; see the lesson sections below.

**Section 1:** Introduction of the types of circuits [2 mins 10s]

**Section 2:** Teaching series and parallel circuits [18mins 44s]

**Section 3:** Examples of series and parallel circuits using textbook [8mins 7s]

**Section 4:** Consolidation of the lesson [5 mins 8s]

### 5.5.1 Victoria PCK and practice

#### a) Knowledge of curricular saliency of the topic

Victoria started by revising the symbols of electric circuit components and current. Similar to Textbook B, she differentiated series and parallel circuits by referring to the concept of current. After that, she drew a series circuit diagram and asked learners if it was an open or closed switch. She then moved on to teach voltage and current for resistors in parallel circuits after learners answered correctly by stating that it is a closed switch. She did not cover the prescribed content in the curriculum about current and voltage for resistors in series circuits. Textbook B covered the prescribed content about voltage and current for resistors in series circuits, using practical investigation activities, diagrams and explanatory texts. In line with the ePCK rubric, Victoria's knowledge of pre-concepts and presentation of content prescribed by the curriculum is *basic*. She only revised what was learnt about current from previous sections and did not revise anything about what was learnt about voltage. Furthermore, she omitted the concept of current through resistors in series and voltage across those resistors.

Victoria linked the concept of current through resistors in parallel circuits to the pre-concept of parallel circuits with multiple pathways for current flow. Textbook B presented current for resistors in a parallel circuit the same way; learners are reminded that a parallel circuit has multiple ways for current to flow before presenting the

concepts of current. Regarding voltage, Victoria stated that the voltage of resistors in parallel is the same, but did not link it to the voltage of the cell/battery. She also did not refer to voltage across the cells, a pre-concept for voltage across resistors in parallel circuits. In Textbook B, the concept of voltage across the resistors is related to voltage across the cell and the concept of voltage across cells was omitted regardless of the curriculum prescribing it. Victoria inadequately covered the concept of current for resistors in parallel circuits by stating that "*the current through the battery is the same as the current through the resistors"*. This is not necessarily true because resistors in parallel divide current according to their resistance. The textbook had a brief text about this, stating that "*the total current is equal to the sum of the current in each resistor*". Similar to Victoria, there was no further explanation, discussion, or examples of current for resistors in parallel circuits in the textbooks.

Victoria did not pay attention to the sequencing and interrelatedness of electrical circuit concepts. She only related current and resistance for resistors in parallel circuits. As for sequencing, it was illogical, because it did not support conceptual development. During the interview, she stated that she would sequence the key ideas from cell, current, and resistance. She was observed starting with current and then with voltage. The textbook sequences concepts from voltage to current for circuits, where the interrelatedness of concepts is evident. Regarding the relevance of learning about electrical circuit concepts, Victoria noted that at home, there are only parallel circuits and dismissed learners' answers that said there is a series connection, too. She noted that if one bulb stops working in a parallel circuit, the other bulb will continue working. The same statement was evident in the textbook. Victoria did not refer to the concept of voltage or current when explaining why at-home bulbs are connected in parallel connection. Consequently, Victoria's knowledge of sequencing, interrelatedness and

relevance of key concepts is *basic,* in line with the ePCK rubric. She does not emphasise key concepts and presents the concepts in a way that develops conceptual development.

Overall, Victoria's knowledge of curricular saliency is allocated at a *basic* level on the ePCK rubric. This is because she did not present all the concepts prescribed by the curriculum or explain their interrelatedness. As discussed in the above paragraphs, she did not pay attention to sequencing the concepts, linking new concepts with pre-concepts, and scaffolding conceptual understanding of key concepts when teaching about the relevance of learning about electrical circuit concepts. Textbook B was allocated a *developing* level in the previous chapter.

**b) Knowledge of learners' understanding of science concepts**

During the interview, Victoria mentioned calculations as the only challenge learners encounter in electric circuits. When she was teaching, I observed that she noticed that learners have a challenge identifying whether resistors are in series or parallel circuits. This challenge is reported in the diagnostic report, where learners are noted to struggle with identifying the type of connection for resistors (Department of Basic Education, 2023). After she realised that learners confuse series with parallel circuits, she used her hands to claim that series refers to horizontal line and a parallel refers to a vertical line. There was no example, discussion, or elaboration about what she meant in this regard. In the next example, learners answered in chorus correctly by saying resistors are in parallel. She concluded that learners understand parallel circuits without engaging them or explaining why it is correct to say resistors are in parallel. This revealed *limited* PCK according to the ePCK rubric because she did not address

learners' challenges adequately by referring to the key concepts of voltage and current.

Victoria's statement that "*the current through the battery is the same as the current through the resistors*" might lead to learners' misconception of the constant current source model, where learners believe that the battery provides constant current irrespective of how the circuit is arranged or changed (Küçüközer & Kocakülah, 2007). This is because she did not elaborate, thereby potentially, enforcing the misconception, which was obviously not her intention. When drawing circuit diagrams, she incorrectly indicated conventional current from the negative to the positive terminal of the battery, irrespective of the textbook indicating conventional current the right way. This might lead to learners confusing electron flow with current flow. Figure 5.4 below shows how she indicated convectional current on the right, and the left is how the textbook indicated it. Indicating the direction of conventional current incorrectly and presenting statements that can enforce misconception reveal *limited* PCK of learners' challenges of electric circuit concepts.

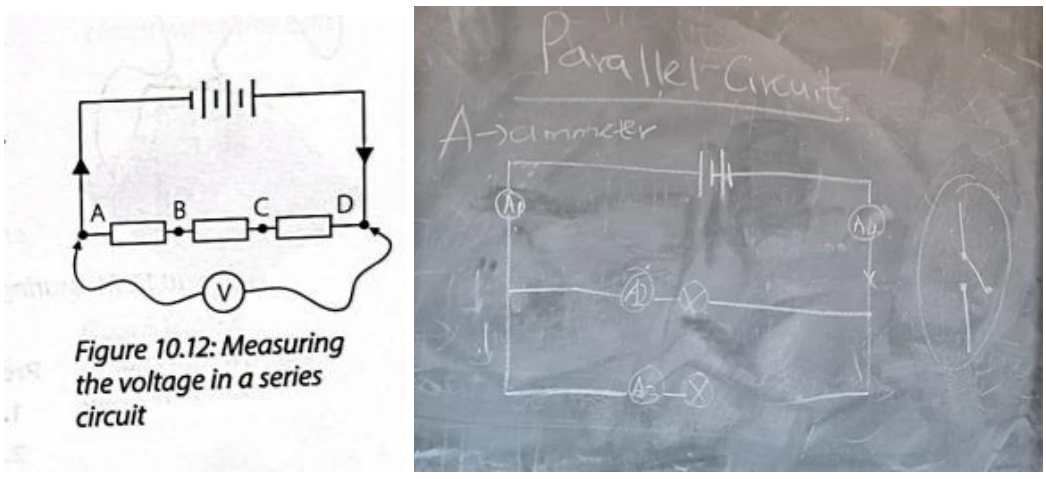


**Figure 5.4: Victoria's representation**

Overall, Victoria's knowledge of learners understanding of science concepts is allocated limited level on the ePCK rubric. This is because data from the interview revealed that she has no understanding of learners' misconceptions and challenges, because the literature shows that learners have misconceptions about simple circuits (Mbonyiryivuze et al., 2019). She only listed calculations, which is not regarded as a misconception. From the classroom observations, she did not address emerging learners' difficulties or explain the statement she presented. Furthermore, Victoria did not have discussions that could have elicited learners understanding of the concepts. Textbook B revealed the *basic* PCK for this component.

**c) Conceptual teaching strategies and representations.**

Regarding representations, Victoria used schematic circuit diagrams from the textbooks and study guide. She only re-drew diagrams from the study guide (see Figure 5.5a above). For the diagrams in the textbook, she referred learners to the page number and figures (such as Figure 5.5 below). The diagrams were not used to explain or emphasise key concepts of voltage, current, and resistance for resistors in electrical circuits. Rather, she used the diagrams to ask basic questions such as:

- *How many cells? How many bulbs? Is it open or closed switch?*
- *What type of circuit is this one? series or parallel one?*

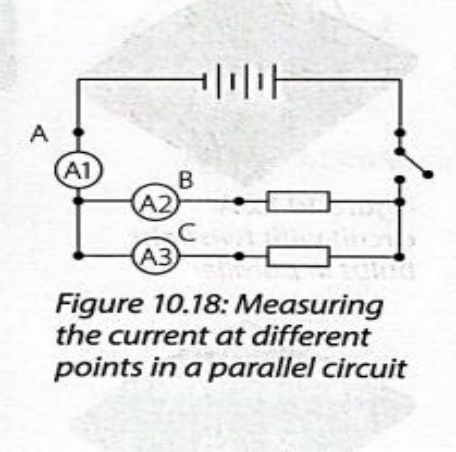


**Figure 5.5: Victoria's representation**

For the diagram in Figure 5.5 above, there was confusion from learners as to whether the circuit has an open or closed switch. Some learners said “open and closed switches”, and she dismissed their answers. She said a circuit diagram cannot have both an open and closed switch. In the VSR interview, she said if she could ask more questions, she would ask about cells and the flow of charges. The textbook did not have any explanatory text about the diagram. The diagram was used for practical activity purposes in order to illustrate how to set up an electric circuit. It can be said that the textbook was not sufficiently educative. It did not support the teacher by guiding them about questions that could be asked, or provide explanatory text about the diagram.

Regarding conceptual teaching strategies, Victoria mentioned questions and answers as the strategy she preferred during the interview. She did not give examples of the type of questions she would ask. The textbook relies heavily on practical investigation activities to present the content of electric circuits. During the lesson, I observed her asking basic questions (see questions above) not directly related to the key concepts of circuits such as voltage and current. She did not engage learners and facilitate

discussions as they were answering. If the learner's answer were incorrect, she would give the correct answer and not comment on the answer given by the learner. This was the same as in the textbook, where there were no discussions or questions about the key concepts of circuits. Victoria did not provide explanations for the important concepts of circuits. Instead, she was reading the material she had word for word without explaining or elaborating. For example, she made the following statement about the voltage of resistors in parallel:

*"*Victoria: *voltage is the same across each resistor connected in a parallel way".*

That is all that she said, and did not provide an explanation as to why it is said that voltage across resistors in parallel can be said to be the same. This is similar to how the textbook presented the voltage of resistors in parallel, i.e. there was no explanatory text examples or discussion, only a practical activity for the voltage of resistors in parallel. As a result, Victoria's knowledge about conceptual teaching strategies including representations is allocated *limited* on the ePCK rubric. As noted in the rubric, questions that elicit a chorus, providing no explanations or discussions and failing to use diagrams to explain important and difficult concepts are regarded as limited. The textbook did not provide educative support to the teacher, it is allocated *basic* in the previous chapter.

### 5.5.2 Victoria's Use of Textbook.

During the interview, Victoria mentioned that she uses the textbook and teacher's guide to prepare for the lessons. During the lesson, I observed her using diagrams from the textbook to ask learners questions. The diagrams were suitable to explain the concept of current and voltage in circuits, but she did not use them for that purpose. At the end of the lesson, she used a textbook to give learners a practical activity about

parallel circuits without explaining it. During the VSR interview, I asked her about a concept she was trying to emphasise with the activity, and she responded as follows:

*Victoria: "I just emphasised the point that they must have that knowledge that the electric is concerned about the switch, the bulb the voltmeter and when you switch, the light must be visible. They must show and see them practically when they switch the bulb."*

It would appear that Victoria recommended the activity for learners to learn about electric circuit components. She did not say anything about the concepts of voltage and current in parallel circuits, which was the purpose of the activity. It can be concluded that Victoria used the textbook for lesson preparations, representations and activity purposes. The influence of the textbook on Victoria's PCK was more evident in the component of conceptual teaching strategies and representations. However, the influence of the textbook was limited because the diagrams did not have explanatory texts, and the school did not have resources for learners to undertake the practical activity suggested by the textbook.

## 5.6 CASE STUDY THREE – ROBBEN

Robben had three years of teaching experience at the time of the study. He also completed undergraduate Physics up to the second-year level as part of his qualification for a Bachelor of Science (BSc) degree. Furthermore, he teaches Physics at Grades 10-12 and did methodology of physics as part of his Postgraduate Certificate in Education (PGCE). It can be assumed that he had adequate content knowledge and PCK to teach electric circuits at the Grade Nine level. The school he was teaching at is poorly resourced. He used Textbooks A and C to prepare for electric circuit lesson and textbook A when teaching the topic. I observed him teaching cells

and resistors in series and parallel circuits. For parallel circuits, I did not observe him teaching all these concepts. The lesson was divided into sections, as shown below. Only specific sections are chosen for analysis.

**Section 1:** Introduction of electric circuits concepts [Time 19mins 40s]

**Section 2:** Teaching cells and resistors in series circuits [Time 23mins 1s]

**Section 3:** Teaching cells and resistors in parallel circuits [Time 24mins 25s]

**Section 4:** Doing examples of series and parallel circuits [Time 12mins 8s]

### 5.6.1 Robben PCK and practice

#### a) Knowledge of curricular saliency of the topic

Robben started the lesson by discussing briefly the concept current, voltage and resistor. The discussion included definitions, units of measurement and instruments to measure current and voltage. He first defined current as "*the rate of charge flow in a closed circuit*", which is different from how both textbooks defined it. He used textbook A to define voltage where he wrote the exact definition on the board, word for word. Learners were referred to the page in textbook A that defines the concept. He then gave a rationale for the connection type of ammeter and voltmeter. Textbook C has the rationale of only the connection of the voltmeter. Robben developed new concepts from corresponding pre-concepts. This was evident when he revised the pre-concept of current to differentiate series and parallel circuits when he was teaching both series and parallel circuits, respectively. This is the same way in which the concept of current is presented in both textbooks. The authors of textbooks A and B referred learners to what was learnt about current in the previous grade when presenting current for

resistors in series and parallel circuits. In line with the ePCK rubric, Robben's knowledge of pre-concepts and developing new concepts from pre-concepts is allocated to the *developing* level. This is based on revising most of the pre-concepts and linking some of those concepts to new concepts.

In terms of concept sequencing, Robben followed the exact sequencing of both textbooks when he presented the concepts of electrical circuits. He revised the relationship between current and resistance when teaching resistors in circuits after he taught cells in circuits. This is similar to how Textbook C sequenced the concepts, except that Textbook C presented the content using practical activities. Robben used a diagram to explain the relationship of the concepts. When it comes to the interrelatedness of these concepts, Robben adequately explained the interrelatedness of voltage with resistance for series circuits similar to the way in which it was explained in Textbook A. He did not relate voltage to energy or voltage to current. Textbook A relates voltage to energy using analogy, and Textbook B relates voltage to current when presenting voltage across cells in electrical circuits. In addition to an explanation of the relationship between voltage and resistance, he explained the relationship between current with resistance for both circuits. The interrelatedness was evident in both textbooks. According to the ePCK rubric, Robben's knowledge of sequencing and interrelatedness of electrical circuit concepts is allocated to the *developing* level because he adequately explained the relationship of the concepts and paid attention to the sequencing of the concepts.

The relevance of learning about electrical circuit concepts was not evident during the lesson. In both textbooks, the relevance of learning about the concepts is made evident only at the end of the topic. When it comes to the presentation of content as

prescribed by the curriculum, Robben discussed all the prescribed concepts by the curriculum for series circuits. For parallel circuits, he covered voltage across the cells and the relationship between current and resistance for resistors. He was however aware that he did not cover all the concepts, where it would appear that he covered all the prescribed content.

Overall, Robben's knowledge of curricular saliency is allocated a *developing* level on the ePCK rubric. This is based on his presentation of the curriculum's prescribed content, logical sequencing, and explaining the interrelatedness of the concepts, as discussed in the above paragraphs. Furthermore, he developed the concept of current from pre-concepts. However, he did not refer learners to pre-concepts of voltage when presenting voltage across cells and resistors in electrical circuits. He also did not cover the relevance of learning about electrical circuit concepts. Consequently, he is not allocated an *exemplary* level. Both textbooks revealed *exemplary* levels in this component.

**b) Knowledge of learners understanding of science concepts**

During the semi-structured interview, Robben mentioned two challenges faced by Grade Nine learners when it comes to electrical circuits. The first challenge is that learners believe that electrons flow from the positive to the negative terminal of the battery as for conventional current, and the second is that learners find it difficult to differentiate between resistor and resistance. None of the challenges are reported as misconceptions or difficulties in the literature. To address the first challenge, Robben provided an explanation about voltage and included the flow of electrons. In the interview, he said he relied on the textbook in order to explain the misconceptions.

*Robben: "…normally I rely on the textbook, starting with the one for the movement for the current and electrons. At least I will explain the knowledge of the textbook in which direction does the electrons travel"*

Textbook C mentions electron flow whenever it explains voltage, but it does not state the direction of the flow of electrons. Robben explained the direction of electrons beyond what was presented in the textbook. Before that, he reminded learners about conventional current, which flows from the positive to the negative terminal of the battery. As for the second challenge, he did not caution learners about this during the lesson by explaining the difference between a resistor and resistance. He explained a resistor but not resistance. In line with the ePCK rubric, this reveals a narrow understanding of learners' misconceptions and challenges of electric circuits, as there are many misconceptions (see section 2.4.1 of Chapter 2).

Robben taught the concept of voltage across cells in parallel in a way that may prevent learners' misconception of the superposition model. The misconception is that learners believe that cell arrangement does not affect the total voltage of the battery (Engelhardt & Beichner, 2004). He used a diagram similar to that found in Textbook A to explain that the total voltage across the cells connected in parallel is the same as for one cell. Furthermore, he reminded learners that this is different for voltage across cells in series by saying, "*remember the cells in series… the total voltage is the sum of the voltage of all the cells*". This reveals *basic* PCK, since he attempts to address learners' misconceptions by providing standardised phrases. In Textbook A, there is a statement that emphasises that, as more cells are added in parallel, the voltage of the cells remains the same.

Learners have a misconception about the resistance of resistors in parallel circuits. They believe that as the number of resistors increases in a parallel circuit, the total resistance will increase (Nkopane et al., 2011). Robben adequately addressed this misconception through explanation, using a circuit diagram and mathematical calculations (see Figure 5.6 below).

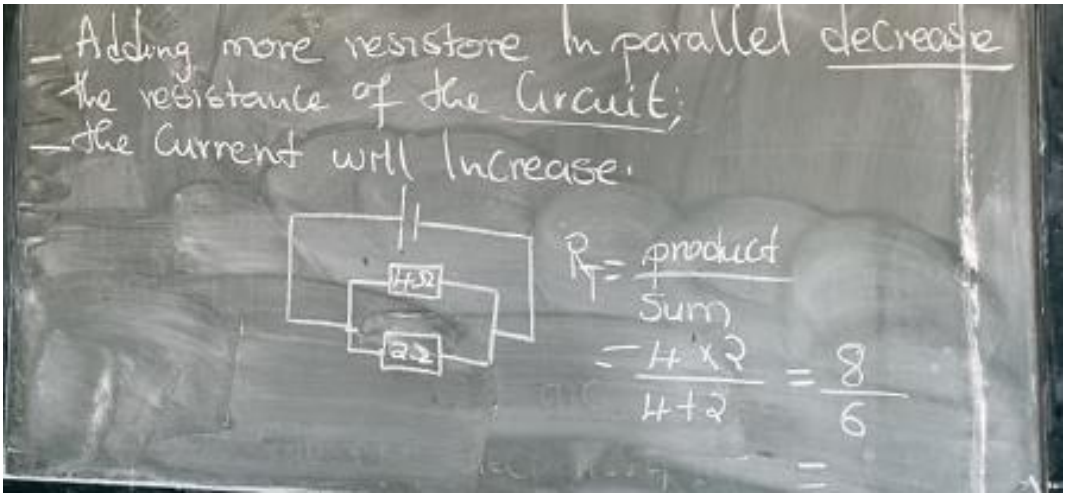


***Figure 5.6: Robben representation***

He explained the statement in Figure 5.6 above in detail. For calculations, he started by referring learners back to resistors in series and calculated the resistance of resistors in series on the side and the resistance of resistors in parallel, as shown above. The calculations showed that for resistors in series, the total resistance increased and for resistors in parallel, the total resistance decreased. In a video-stimulated recall (VSR) interview, he noted the calculations were to support his explanations. None of the textbooks had calculations. To explain further, he used the example of a diagram of bulbs in series and parallel circuits and referred learners to brightness and ammeter reading. This is similar to a practical investigation activity about the brightness of bulbs in parallel circuits presented in Textbook C. He did not do the practical investigation activity, but explained it in theoretical terms.

His explanation was that as more bulbs are added in parallel, the brightness of bulbs will increase because the decrease in resistance means more current will flow. This statement can enforce the misconception of learners' reasoning about voltage as a consequence of current. This is because, according to Robben, the brightness of the bulbs depends on current since when more current flows through the bulbs, the brightness increases. The brightness of the bulbs does not depend on current; it depends on voltage, so the bulbs will have the same brightness because the voltage across the bulbs is equal. Both textbooks used analogies in addition to practical investigation activities in order to present the resistance of resistors in parallel. Robben did not use analogies.

Although Robben made an effort to address learners' misconception of parallel circuits, the conclusion he gave may enforce misconception. He concluded by stating that current is inversely proportional to resistance. Textbook C presented the same statement. This implies that a change in current in the circuit will affect the resistance of the circuit, which is not in fact the case. Resistance is not determined by current; it is a property of the resistor. Learners may be lead to think that a change in current affects resistance due to the use of the expression of *"inversely proportional*". It must be noted that he did not talk about change in the current. He only talked about the change in resistance.

Overall, Robben's knowledge of learners' understanding of science is allocated to the *basic* level on the ePCK rubric. Even though the interview data revealed a narrow understanding of learners' misconceptions and challenges, he showed awareness of certain misconceptions and challenges during the lesson. He addressed the superposition model and parallel circuit misconception through explanations and the

use of diagrams to support the explanations provided, as discussed in the above paragraphs. However, some statements he provided can enforce misconceptions, and he often provided standardised phrases to address some challenges that learners have or can arise during the lesson. Both textbooks, A and C, revealed *basic* PCK for this component.

**c) Knowledge of conceptual teaching strategies and representations.**

Robben used circuit diagrams supplemented by mathematical equations as representations when teaching electric circuit concepts. In terms of diagrams, he used picture and schematic circuit diagrams similar to those found in the textbooks to explain electrical circuit concepts. In Figure 5.7 below, he introduced a series circuit and drew a picture diagram the same as in textbook C. He added a schematic circuit diagram, which was not available in the textbook (see Figure 5.7 below). He did the same thing for the diagrams he used to teach voltage across cells in parallel. Except this time, he used Textbook A, which had a picture and schematic circuit diagram. The textbook had a practical investigation activity.

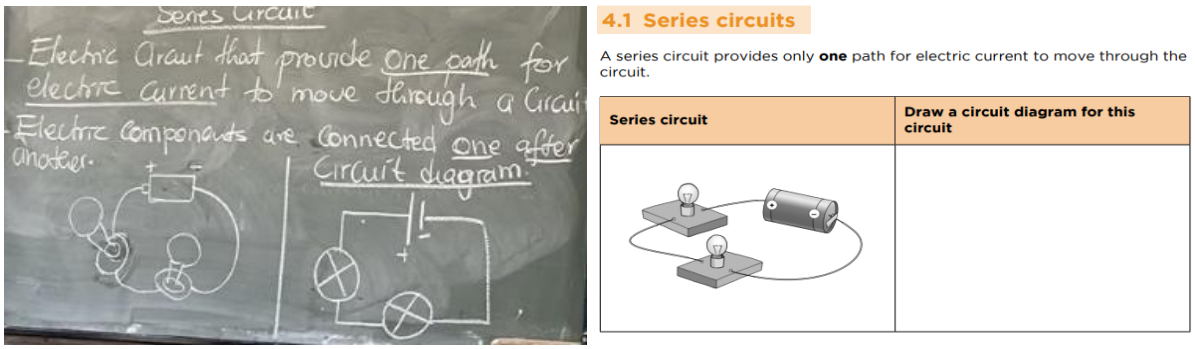


***Figure 5.7: Robben representation***

During the semi-structured interview, Robben confirmed that he relies on circuit diagrams from the textbook while other diagrams are from him. When I asked him how he uses the diagram, his response was:

*Robben: "I use them to explain, to demonstrate that this is how a series circuit looks like; I draw it that way to show them what it looks like or a parallel circuit how it looks like."*

He explained how he uses circuit diagrams from textbooks to support his explanations, because he cannot do the demonstrations due to a lack of facilities and resources. When asked about conceptual teaching strategies, he said he prefers demonstrations to show learners what he is explaining. During the lesson, it was evident that he valued demonstrations. This was seen whenever he used diagrams that depicted bulbs, for instance, when teaching the concept of voltage across cells in series, he used diagrams one and two. In diagram one, there was one bulb and one cell, and in diagram two, there was still one bulb, but now subsequently two cells. He asked learners which bulb would be brighter. A learner said bulb in diagram two, and Robben went on to explain why this is the case, by referring to voltage instead of probing learners further. In textbook A, this was presented using a practical activity where the number of cells was increased from one to three, and one bulb was used. The textbook did not have a diagram, it had only demonstration instructions. In the interview, he mentioned that he used practical investigation activities as a guide, but he did not do the activities practically. In a video-stimulated recall (VSR) interview, I asked him why he did not use videos or simulations. He responded that he wanted to use simulation from textbook C but could not download it because the link was not working.

For conceptual teaching strategies, Robben drew from questions and explanations evident in the textbook to teach electrical circuit concepts. He used diagrams and equations when explaining the concepts and asking questions. For the use of the equation, he represented voltage across resistors in series as $V_T=V_1 + V_2$. When answering questions from textbook activities, he used this equation to determine the voltage across resistors in series (see Figure 5.8 below on the right side). Both textbooks did not use the equation but had questions where it was applicable. Figure 5.9 below shows the circuit diagram that Robben redrew from Textbook A on the board since some learners did not have textbooks. The diagram was used to explain the voltage across resistors in a series circuit and the interrelatedness of voltage and resistance. He only asked the questions that were evident in the textbook. When he asked learners the questions, he often directed them to the pages in the textbook or notes where they discussed the concepts. Learners were not asked to elaborate on their answers. Whenever a learner gave an answer, he would explain why the answer was correct, without giving learners the opportunity to explain their answers. This led to less discussions.

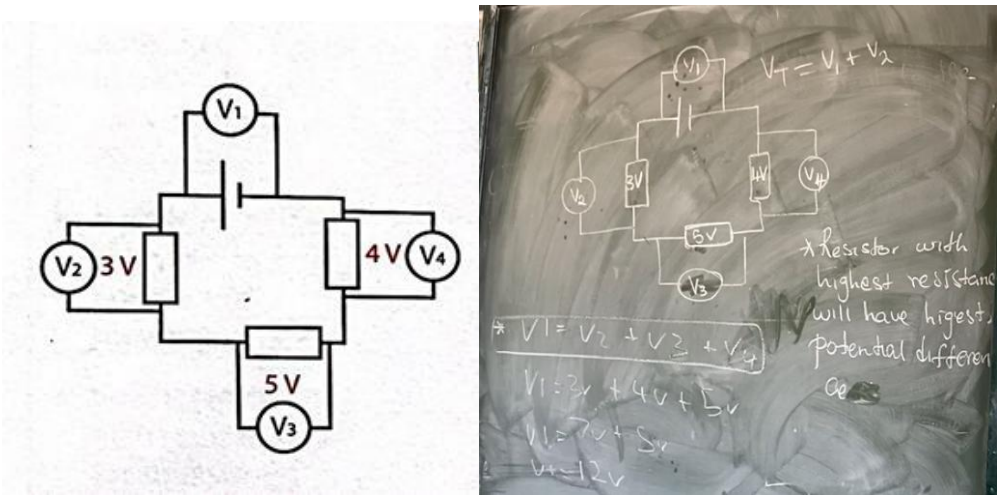


***Figure 5.8: Representations used by Robben***

Overall, Robben knowledge of conceptual teaching strategies and representation is allocated *developing* level on the ePCK rubric, the same level that both textbooks are allocated. As discussed in the above paragraphs, he provided sufficient explanations and used representations effectively to explain difficult and important concepts. Although he used the questioning method, he did not engage learners in discussions; hence, he is not allocated an *exemplary* level in the ePCK rubric.

### 5.6.2 Robben use of textbook

Robben's reasons for using textbooks include the way in which the textbooks present content for Grade Nine learners. In his own words, he said:

> *Robben: "I use the textbook to check how they explain electric circuit concepts for the Grade Nine level because I know the concepts at the Further Education and Training (FET) level. The definitions might be different for FET and Grade Nine".*

It can be seen from the above statement that he referred to the textbooks to determine how the textbooks unpack the content of electric circuits for Grade Nine learners, knowing the content from the perspective of Grade 10-12. He further noted that he relied on the diagrams from the textbooks, but that not all diagrams were from the textbook. I observed him using diagrams from the textbook in class and doing textbook A activities with the learners. He would refer learners to Textbook A when he was asking questions. Learners would then reply only after he told them to check their textbooks. It was evident that the presentation of the content of electric circuits in textbooks influenced him regarding how to approach the topic.

To some extent, the PCK revealed in textbooks resembled Robben PCK. For instance, in the component of curricular saliency, he followed the textbook sequencing and

explained the interrelatedness of the concepts. At times, he would adapt the textbooks to suit his context. For instance, he asked learners about the brightness of the bulbs, in a way similar to the practical activity instructions found in the textbook. This idea was from the textbook. His response below supports this:

*Robben: … the textbook I used shows the different, like when you were explaining the effect of brightness. It shows a circuit diagram with only one bulb, next when you add another one where learners will have to explain which one will be brighter. It becomes easy for them to see.*

### 5.7 CASE STUDY FOUR – STEVE

At the time of the study, Steve had 30 years of experience teaching Natural Sciences at primary and secondary schools. In addition, he had 20 years of experience teaching Physics at Grade 10-12 level. His qualifications include a senior primary teachers' diploma (SPTD) and an advanced certificate in education (ACE), majoring in science education. It can be assumed that he had adequate content and PCK to teach electric circuits at the Grade Nine level. The school had limited resources. He used textbook A and circuit board as resources to teach electric circuits. I observed him teaching cells and resistors in series and parallel circuits in one lesson of 60 minutes. See lesson sections below.

**Section 1:** Revision of learners' prior knowledge [06 mins 26s]

**Section 2:** Teaching cells in series circuits [21mins 4s]

**Section 3:** Teaching resistors in a series circuit [4mins 2s]

**Section 4:** Teaching cells and resistors in parallel circuits [Time 16mins 37s]

**Section 5:** Consolidation [4mins 34s]

### 5.7.1 Steve PCK and practice

#### a) Knowledge of curricular saliency

Steve revised the components of electric circuits, resistors and current. He briefly explained the resistor and defined current as the flow of electric charges through the conductor. The definition of current is the same as that used in Textbook A. After definitions, he drew a diagram which he used to explain the current flow for resistors in parallel. In Textbook A, the authors revised the current flow for resistors in both series and parallel circuits. The concept of voltage, as covered in the previous section, was not revised. In Textbook A, the concept of voltage is briefly explained before presenting the concept across cells in series. Although he briefly revised the current, he did not link or develop new concepts from corresponding pre-concepts. Consequently, his knowledge of pre-concepts and linking new concepts with pre-concepts is *basic*, according to the ePCK rubric. He did not revise voltage and link the new concepts with the pre-concepts.

Steve sequenced the concepts from current to voltage, which differs from how textbook A sequenced the concepts. Textbook A starts with the concept of voltage and then current. In the semi-structured interview, I asked him about the sequencing of key concepts, and he responded as follows:

***Steve:*** *"you may start with the current and then the voltage there is no problem with it. You must explain the flow of current first, in parallel and in series. After that, you also define the flow of voltage in current and in series. Then, after that, as long as they understand the current in series and parallel, then now you can introduce the resistance".*

From the above response, Steve emphasises starting with the current. He states that one must explain the current in electrical circuits and then move to voltage, which will then be followed by resistance. It is important that concepts be sequenced so that the sequencing will support conceptual development. Even though there is no one way to sequence the concepts, it might be better to start with voltage and relate it to energy, then move to current. This can explain the cause and effect of electrical concepts, leading learners to differentiate between voltage and current.

In terms of the interrelatedness of electrical circuit concepts, Steve explained the interrelatedness of current and resistance when he taught resistors in parallel circuits alone. When he taught cells, the voltage was related to current. At no point did he relate voltage to energy and voltage to resistance. Textbook A explained the interrelatedness of voltage and resistance. In line with the ePCK rubric, Steve reveals *developing* PCK for sequencing and interrelatedness of the concepts. His reasons for sequencing do not necessarily support conceptual development, and he did not explain the interrelatedness of some concepts as mentioned above.

Regarding relevance of learning about electrical circuits, Steve related circuits to learners everyday lives in a way that scaffolded the concept of current. He did so by demonstrating that when two bulbs are connected in parallel, and the filament of one bulb fuses, the other bulb will continue to glow. He then explained that the current will continue to flow through the other resistor. That is similar to what is presented in Textbook A, except that this textbook has only an explanation and no demonstration. Regarding presenting content prescribed by the curriculum, Steve covered most but not all of the prescribed concepts. The textbook covered all the concepts prescribed by the curriculum. He did not teach voltage for resistors connected in series and

parallel circuits. The concept of voltage was adequately covered only for cells in series and parallel circuits. He covered the concept of the current for resistors in both series and parallel circuits. According to the ePCK rubric, Steve reveals *developing* PCK where he presents most concepts prescribed in the curriculum and scaffolding the concept of current when relating circuits to learners' everyday lives.

Overall, Steve's knowledge of curricular saliency is allocated to the *developing* level on the ePCk rubric. As discussed above, he explained the interrelatedness of concepts, presented the prescribed content and related the concepts to learners' everyday lives. However, he did not revise all pre-concepts, and the sequencing does not support conceptual development. Textbook A revealed *exemplary* PCK for this component.

**b) Knowledge about learners understanding of science concepts**

During the semi-structured interview, Steve mentioned learners' challenges in identifying resistors in series and parallel circuits. This challenge has been consistently reported in diagnostic reports throughout the years (Department of Basic Education, 2023). When I asked him how he would address the challenge, he said he would give learners more activities from the textbook and other materials. However, he did not do that when he was teaching. Instead, he drew a circuit diagram of three resistors, where two were in parallel, and the third was in series with those. This manner of example can be confusing for learners at the Grade Nine level. In particular, Steve did not explain to learners how the resistors are connected and how to identify resistors connection in circuits. Textbook A have resistors in series and parallel circuits separately, where there is no diagram that has resistors in series and parallel at the same time. This reveals *basic* PCK according to the enacted PCK rubric. Even though

Steve mentioned learners' challenges, he did not address the challenge during the lesson.

Steve presented the concepts of voltage and current for cells and resistors simultaneously. He did not teach the concepts first for cells and then for resistors, as the textbook presented them. Learners were confused about current through cells and resistors in series circuits. One learner asked for clarity by asking the following question:

*Learner: "You [referring to the teacher] said for a series connection, the voltage increases but the current remains the same"*

He did not address the question. He went on to talk about current through cells in parallel circuits rather than referring to resistors in series circuits. He did not realize that earlier, he said the current would remain the same immediately after talking about voltage increasing for cells in series connection. He did not make it clear that the current does not change for resistors in series connection but it increases as the voltage increases because of adding more cells. This reveals *limited* PCK according to the ePCK rubric because he did not facilitate discussions that can uncover learners' understanding of the concept of current.

Steve presented the concepts of voltage and current in a way that may enforce misconception, where learners fall under the impression that voltage is a consequence or property of current, not an independent variable (Engelhardt & Beichner, 2004). Steve started by presenting the current before voltage. Furthermore, he relates the bulb's brightness to current instead of voltage. He stated that the current increases as the brightness increases when he adds more cells in series, and if the current is low

or weak, the brightness will be weak. He did the same when he was teaching cells in parallel circuits. He said:

*Steve: If you increase the number of cells in parallel, the current will remain the same.*

The statement can enforce another misconception. Learners believe that the battery provide constant current irrespective of how electric circuit components are arranged (Cohen et al., 1983). Textbook A did not have the statement. In the textbook, voltage is presented first, after that current is presented. The concepts are not used interchangeably as it was observed in the lesson. Steve reveals *limited* PCK according to the ePCK rubric, having revealed a lack of understanding of learners' misconceptions about the key concepts.

Overall, Steve's knowledge of learners' understanding of electrical circuit concepts is allocated a *limited* level in line with the ePCK rubric. Although he mentioned learners' challenge of identifying resistor connections in circuits, he revealed no understanding of learners' common difficulties and misconceptions reported in the literature. He presented some concepts in such a way that may enforce misconceptions, as discussed above. Furthermore, there were no discussions that could elicit learners' understanding of concepts. Textbook A revealed *basic* PCK in this component.

**c) Knowledge of conceptual teaching strategies and representations**

Steve used demonstrations extensively to teach voltage, current, and resistance for cells and resistors in electrical circuits. He used the instructions provided by textbook A to conduct demonstrations in order to teach voltage across the cells and current through the cells for series and parallel circuits. Figure 5.9 below shows how the

textbook presents cells in series and how Steve presented these in class. It is evident that the textbook informed his PCK concerning the use of demonstrations as representations. He used the same outline and presentation of results and gave a conclusion as is done in Textbook A. Furthermore, he slightly changed the question in the instructions. The question was, “what does the brightness tell you about the circuit?” He rephrased this to an investigation question that stated: “If you increase the number of cells, what happens to the brightness?” He then went on to demonstrate to the learners. After he had demonstrated this, he randomly selected three learners to do the same demonstrations. The learners did it correctly, as he had done.

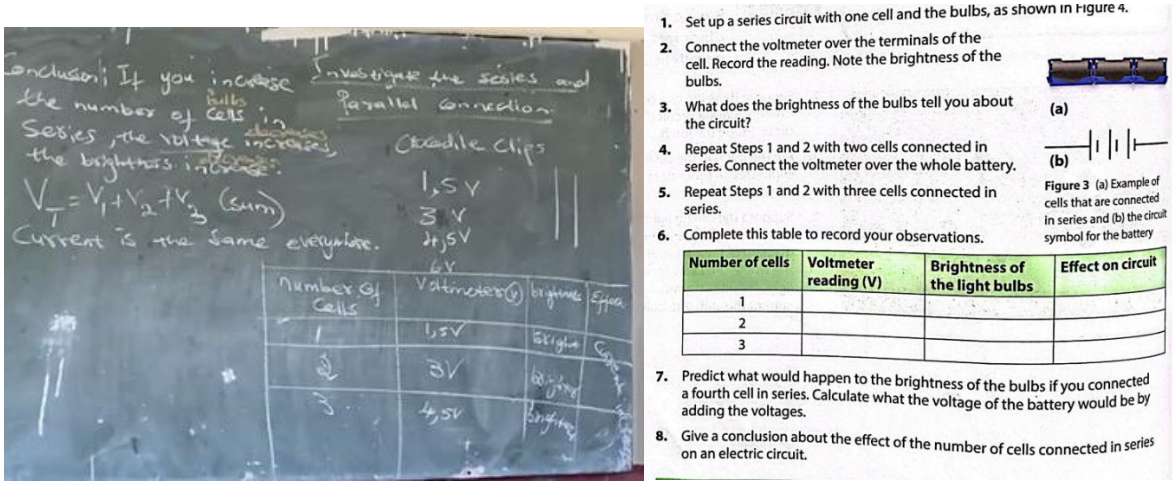


***Figure 5.9: Practical investigation outline***

He seldom asked questions and provided explanations during the investigations for conceptual development of the key concepts of electrical circuits. He asked learners what they noticed about the brightness of the bulbs as he added cells. Learners said the brightness increases. He did not probe learners further, but rather told them that brightness increases because current increases. In the conclusion, he referred to voltage to explain why the brightness increased (see Figure 5.9 above). This was presented using the equation as $V_T = V_1 + V_2 + V_3$. For the cells in parallel, he followed

the same method. The conclusion was represented as $V_T=V_1=V_2=V_3$. According to the ePCK rubric, Steve reveals *basic* PCK for the use of representations. This is based on not asking questions that can elicit learners' thinking and not having discussions. Furthermore, he did not provide explanations for the key concepts.

Steve mentioned the experimental method as a preferred teaching strategy during the interview. However, he did not follow the outline of the experiment; he followed the outline of investigation activities presented in textbooks. He reflected on the use of demonstrations during the video-stimulated recall (VSR) interview and said they were effective and learners understood. The investigation activities of adding more bulbs in series and parallel circuits while keeping the number of cells the same were not from the textbook. The textbook used resistors of different but known resistances in order to present concepts of voltage, current, and resistance for resistors in circuits. He started with a demonstration and provided a conclusion similar to the outline from the textbook for presenting electrical concepts for cells in electrical circuits. Learners were not engaged. There were no questions or explanations to enhance conceptual understanding during the investigation. He provided the following conclusion for bulbs in series and parallel, respectively:

- *"If you increase the number of bulbs in series, the voltage decreases and the brightness decreases"*
- *"If you increase the number of bulbs in parallel, the brightness is the same"*

The first statement is about bulbs in series. He did not explain that the voltage that decreases is the voltage across the bulbs while the voltage across the cells remains the same. For the Grade Nine level, learners do not learn about the internal resistance

of the battery, so it can be said that the voltage across the cells remains the same, where we ignore the internal resistance of the battery. The second statement concerns bulbs in parallel. Indeed, the brightness will remain the same, but then he did not explain why the brightness does not change as in a series circuit.

Steve's teaching strategies encourage rote learning as opposed to conceptual reasoning and critical thinking, as discussed above. This was also evident when he taught the relationship between current and resistance for resistors in parallel circuits. He asked a leading question by asking whether the larger resistor would get a smaller current or vice versa for resistors in parallel. Learners noted that the same current, dismissed the answer and gave the correct answer. He did not allow learners to figure out the answer by guiding them. His focus was on presenting the facts regarding when the current that passed through the resistor with the highest resistance will be less and vice versa. According to the ePCK rubric, this reveals *basic* PCK. The textbook presented the relationship of current and resistance adequately using analogies, and circuit diagrams with questions in activities.

Overall, Steve's knowledge of conceptual teaching strategies and representations appears to be *basic* level on the ePCK rubric. As discussed above, Steve's teaching strategies support rote learning rather than conceptual reasoning and critical thinking. He seldom provided explanations and asked questions that elicited learners' thinking and involved them in the lesson through discussions. Furthermore, the use of representations was not for challenging concepts. The representations were used to confirm the principles of electric circuits. The textbook he used is allocated a *developing* level in the previous chapter

### 5.7.2 Steve's use of textbook

Steve used textbooks to prepare for the lesson on electric circuits. This is supported by what he said during the interview when asked about the use of textbooks. He mentioned Textbook A, the teacher's guide and the Grade 10 Physical Sciences textbook as resources he used to prepare for the lesson. I asked him how he used the textbooks, and he said “for lesson planning”, without elaborating. This means one cannot infer which component of PCK was informed by the use of the textbook during lesson preparations. During the lesson, the use of textbook was evident in the PCK component of conceptual teaching strategies and representations. He used the instructions provided by the textbook in practical investigation activities to present the content of electrical circuits. This provides evidence that Steve PCK resembles PCK revealed in the textbook regarding conceptual teaching strategies and representations. In terms of the component of curricular saliency, the textbook influenced Steve PCK to some extent, where he used some aspects of the textbook, such as the relevance of the concepts.

## 5.8 OVERVIEW OF TEACHERS ePCK AND PCK REVEALED IN TEXTBOOKS

Table 5.2 below shows the results of the scores of teachers' ePCK and PCK revealed in textbooks. As the scores on the table show, the quality of PCK revealed in textbooks is higher than that of teachers' enacted PCK in most components. This is because even though the textbooks afforded teachers opportunities to develop their PCK, the teachers did not utilise some of those opportunities. The textbooks influenced teachers' PCK more in the knowledge component of curricular saliency and representations used in conceptual teaching strategies than in the knowledge

component of learners' understanding of electrical circuit concepts. Further discussion on the findings will be presented in the next chapter.

**Table 5.2: Summary of enacted PCK of teachers in relation to PCK revealed in textbooks**

| Participants | Knowledge of curricular saliency | Knowledge of learners' understanding of science concepts | Knowledge of conceptual teaching strategies and representations |
|---|---|---|---|
| **CASE STUDY ONE: NKATEGO** | | | |
| Nkatego enacted PCK | Developing | Basic | Basic |
| Textbook A revealed PCK | Exemplary | Developing | Developing |
| **CASE STUDY TWO: VICTORIA** | | | |
| Victoria enacted PCK | Basic | Limited | Limited |
| Textbook B revealed PCK | Developing | Basic | Basic |
| **CASE STUDY THREE: ROBBEN** | | | |
| Robben enacted PCK | Developing | Basic | Developing |
| Textbook A revealed PCK | Exemplary | Developing | Developing |
| Textbook C revealed PCK | Exemplary | Basic | Developing |
| **CASE STUDY FOUR: STEVE** | | | |
| Steve enacted PCK | Developing | Limited | Basic |
| Textbook A revealed PCK | Exemplary | Developing | Developing |

## 5.9 CONCLUSION

In this chapter, I analysed the ePCK of four Natural Sciences teachers in relation to the PCK revealed in the textbooks that they used. I looked for evidence that reflects teachers' enactment of the collective PCK presented in textbooks. I used the ePCK rubric to score teachers' ePCK based on *limited, basic, developing, and exemplary* levels per component of PCK, similar to how textbooks were analysed. In the next chapter, I address the research questions and discuss how the PCK revealed in textbooks influences teachers' enacted PCK. Furthermore, I provide the conclusion and limitations of the study.

# CHAPTER 6: DISCUSSION AND CONCLUSION

## 6.1 INTRODUCTION

This chapter discusses the research findings and conclusion of this study, providing an overview of this study by summarising the preceding chapters. This is followed by addressing the research questions and discussing the findings guided by this study's research questions and objectives. After this, I will discuss the findings that emerged which fall beyond the objectives of this study. This will be followed by the limitations of the research findings and recommendations for future practice and research based on the findings of this study. Lastly, I present a personal reflection and conclusion on this study.

## 6.2 OVERVIEW OF THE STUDY

The main goal of this study was to investigate the influence of PCK revealed in Natural Sciences textbooks on teachers' ePCK when they teach the curriculum topic of electric circuits. Given that PCK is context-specific (Grossman, 1990), it is essential to state the context in which the study took place. This study was based on public non-fee-paying secondary schools in Sekhukhune East in Limpopo Province. There is a lack of resources such as laboratories and informational and communication technology (ICT) tools, which are important for teaching science. Consequently, schools rely on textbooks as the main curriculum material for teaching science.

The following objectives were developed to meet this goal:

- The first objective was to conduct an in-depth content analysis of the PCK revealed in the Natural Sciences textbooks about electric circuits at the Grade Nine level used by teachers in this study.

- The second objective was to investigate how the PCK revealed in Natural Sciences textbooks impacts teachers' enacted PCK about electric circuits when planning and teaching electric circuits.

The curriculum topic of electric circuits was chosen because teachers find it challenging to teach (Gunstone et al., 2009), and learners have difficulties and misconceptions that have been documented since the early 1980s (Cohen et al., 1983; Shipstone, 1988). The misconceptions are persistent to change even after instruction both locally (Kapartzianis & Kriek, 2014) and internationally (Setyani & Handhika, 2017). As such, it is expected that textbooks as the primary curriculum materials, present the content in such a way that can prevent and address learners challenges. This study was conducted under the assumptions that if the textbook present the content in a way that emphasises key concepts and draws learners' attention to common difficulties and misconceptions of fundamental concepts, while also suggesting strategies and representations to address those difficulties, then the textbook can contribute to the development of teachers ePCK.

PCK is usually associated with teachers, not textbooks. However, in this study, I argued that PCK can also be associated with textbooks, given that textbooks transform the content of topics such as electric circuits for learners' and teachers' comprehension. The RCM of PCK (Figure 6.1 below) is used as a conceptual framework for this study investigating PCK at a topic-specific level (refer to Chapter 2 for a discussion of the model). Similar to Mazibe and Rollnick (2023), the PCK revealed in textbooks is placed within the realm of collective PCK. As shown in the model, collective PCK influences teachers' personal and ePCK during planning, teaching and reflection.

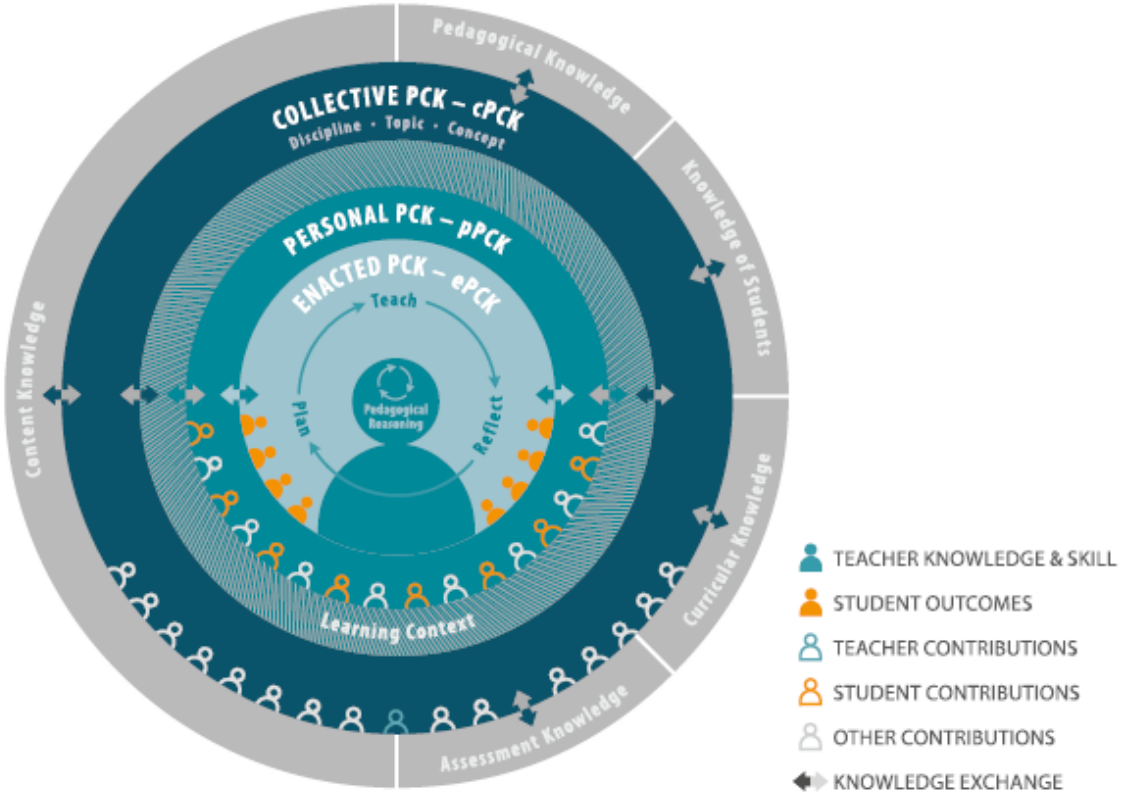


***Figure 6.1: Refined Consensus Model of PCK***

To investigate the collective PCK revealed in the textbooks and the level at which it influences teachers' ePCK, I used PCK components of knowledge of: *i) curricular saliency; ii) learners' understanding of electric circuit concepts; and iii) conceptual teaching strategies and representations*. Data that reflect PCK revealed in textbooks was collected from three textbooks used by the participating teachers and analysed using content analysis in Chapter 4. For data that reflect teachers' ePCK, I was guided by the model and collected data through classroom observations (teach) and interviews (plan and reflect). The data is analysed using content analysis with PCK components as themes in Chapter 5. Two rubrics were used to assess the quality of PCK revealed in textbooks and teachers' enacted PCK, respectively.

## 6.3 ADDRESSING THE RESEARCH QUESTIONS

Primary and secondary research questions were formulated to investigate the phenomenon under the study. I will address the secondary research questions first and then conclude by addressing the primary research question.

### 6.3.1 First secondary research question

- *How do the Natural Sciences textbooks present the prescribed content of electric circuits regarding selected PCK components?*

**Knowledge of curricular saliency**

Textbooks A and C revealed *exemplary* PCK, while Textbook B revealed *developing* PCK for knowledge of curricular saliency. All the textbooks have evidence of pre-concepts from previous grades and sections. Furthermore, the textbooks linked the new concepts with the corresponding pre-concepts. This was more evident in textbooks A and C than in textbook B. The sequencing of concepts evident in textbooks is generally from voltage to current for cells and resistors in electrical circuits. The exception was textbook C, which sequenced the key concepts from voltage to current for resistors in series and current to voltage for resistors in parallel circuits. Sequencing concepts should be in a way that can support conceptual development. In this case, sequencing concepts from voltage to current can help with the cause and effect of electrical circuit concepts. It must be noted that none of the textbooks explicitly explained the cause and effect of voltage and current. Nevertheless, textbooks A and C referred to current when presenting voltage across cells in electrical circuits. This is regarded as sufficient for the cause and effect of voltage and current.

The interrelatedness of key concepts is adequately explained in textbooks A and C. However, the key concepts in Textbook B are only stated but not explained. This is one of the reasons why the textbook was allocated to *developing* PCK. The other reason is that the textbook does not scaffold conceptual understanding of key concepts regarding their relevance. Also, the textbook omitted the concept of voltage across cells in parallel connection. Textbooks A and C scaffold conceptual understanding of current and voltage for the relevance of learning about electrical circuits when relating the content to learners' everyday lives and the concepts of the next grades. In addition to that, the two textbooks present all the prescribed concepts by the curriculum. Hence, the textbooks reveal *exemplary* PCK according to the revealed PCK rubric. In conclusion, the knowledge of curricular saliency evident in textbooks can support teachers in developing their PCK for knowledge of curricular saliency.

**Knowledge of learners' understanding of electric circuit concepts**

For knowledge of learners' understanding of electrical circuit concepts, all textbooks revealed *basic* PCK. The textbooks presented the key concepts with no conceptual errors. Some explanatory texts evident in textbooks can be a starting point to address some of the common difficulties and misconceptions of the topic. For instance, Textbook A has explanatory texts relevant to learners' alternative conception of the voltage across the cells in electrical circuits. On the other hand, Textbook B includes arrows in diagrams that clearly show the direction of conventional current. As for Textbook C, explanatory text and analogy are relevant to learners' alternative conception of parallel circuits. Although the textbooks present key concepts in a way that can prevent and address learners' misconceptions, the textbooks do not explicitly

reveal that those are learners' alternative conceptions. Textbooks B and C use boxes titled tips, remember and take notes, where they can draw learners' attention to common difficulties and misconceptions. However, the textbooks present standardised phrases such as “current is the same through resistors in series connection”; and language issues such as “a battery is a group of cells”. To address learners' challenges, textbooks suggest practical activities prescribed in the curriculum. In addition, Textbook A has questions in activities that can be used to address learners' alternative conceptions of current through resistors in series and the relation of resistance and current in parallel circuits.

**Knowledge of conceptual teaching strategies and representations**

Regarding knowledge of conceptual teaching strategies and the use of representations, textbooks A and C reveal *developing* PCK, while Textbook B reveals *basic* PCK. The representations in textbooks are schematic circuit diagrams, often in picture format. There were explanatory texts for the diagrams for textbooks A and C, while textbook B had none. Additionally, the textbooks provide instructions on conducting demonstrations for presenting voltage across the cells in electrical circuits. Textbooks A and C use analogies in addition to diagrams and practical demonstrations. Regarding conceptual teaching strategies, textbooks A and C provide explanations, and questions are evident in the activities and/ or discussions. The teaching strategies suggested in textbooks A and C sufficiently support conceptual reasoning while encouraging rote learning. Consequently, the textbooks were allocated a *developing* level on the revealed PCK rubric. Textbook B suggests strategies that encourage rote learning as there are no explanations or questions that can support conceptual reasoning in practical activities.

### 6.3.2 Second secondary research question

- *How does the PCK revealed in Natural Sciences textbooks impact in-service teachers' PCK when preparing to teach electric circuits?*

It was found that the textbook knowledge of curricular saliency had minimal influence on participating teachers' ePCK. During the interview, the participating teachers mentioned the main concepts for Grade Nine electric circuits that were not stated in textbooks or mentioned as pre-concepts in textbooks. When it comes to sequencing, the participating teachers sequenced the concepts differently from textbook sequencing, and could not explain how the concepts are interrelated when asked about the rationale for their sequencing. However, there were instances where the participating teachers mentioned concepts that were evident in textbooks and the interrelatedness of those concepts. In terms of learners' understanding of the electric circuit concept component, there was no evidence that the textbook knowledge influenced teachers' knowledge.

Concerning the knowledge component of conceptual teaching strategies and representations used to present the content of electric circuits, the textbook knowledge influenced participating teachers ePCK. For instance, Nkatego mentioned that she refers to textbook examples and circuit diagrams suitable to present key concepts for resistors in series and parallel circuits. On the other hand, Robben referred to explanations evident in textbooks because he wanted to explain concepts in such a way that Grade Nine learners could grasp. Victoria and Steve did not elaborate on how they used the textbooks. The two teachers said they used the textbook for lesson preparations without elaborating further, even when prompted. Consequently, it

cannot be inferred which aspects of textbooks influence their knowledge of conceptual teaching strategies and representations.

### 6.3.3 Third secondary research question

- *How does the PCK revealed in Natural Sciences textbooks impact in-service teachers' enacted PCK when teaching electric circuits to Grade Nine learners in the classroom?*

In addressing this question, I discuss the influence of PCK revealed in textbooks per PCK component. It was found that PCK revealed in textbooks influenced teachers' ePCK more during teaching as compared to when teachers were preparing for the lesson.

**Knowledge of curricular saliency**

As discussed in the previous research question, textbook knowledge of curricular saliency had minimal influence on teachers' ePCK when preparing for the lesson; this was not, however, the case when it came to teaching in the classroom. Participating teachers presented the pre-concepts of the previous grades for the concept of current in the same way as it was presented in the textbook. Often, certain teachers presented new concepts similar to the way in which the concepts were presented in the textbook by linking the new concepts with corresponding pre-concepts. This was evident in Nkatego and Robben's lesson when teaching the concept of current through resistors connected in series. Some teachers' sequencing and interrelatedness of concepts resemble textbooks sequencing and interrelatedness of the concepts. For instance, Robben and Steve followed the sequencing of Textbook A, which presented the concept of voltage first, followed by current for cells and resistors in series and parallel circuits.

For the interrelatedness of concepts, all participating teachers related current and resistance for electrical circuits similarly to how it was presented in textbooks. Robben also related voltage to resistance for resistors in series in the same way as in textbook A. None of the teachers related voltage to energy, which implies that teachers' interrelatedness of concepts was limited to how it was presented in textbooks. Also, for the relevance of concepts in terms of the application of electrical concepts in real life, teachers were limited to the lighting system presented in textbooks. They did not go beyond relating electrical circuits to learners' lives in different ways than what was done in the textbooks. For the presentation of concepts as prescribed by the curriculum, the participating teachers presented concepts similarly to the textbooks. However, it was not all of them. Victoria omitted concepts even though they were presented in the textbooks. In addition, Nkatego included Ohm's law prescribed for higher grades. Overall, the influence of textbook knowledge on curricular saliency was more evident during teaching than when teachers were preparing for the lesson.

**Knowledge of learners' understanding of electric circuit concepts**

Concerning knowledge of learners' understanding of electric circuit concepts, textbook knowledge had the least influence on participating teachers' ePCK. For Steve and Victoria, no link was found between how the textbooks they used presented content and how they presented the content in class when teaching. Victoria showed no awareness of learners' difficulties and misconceptions. She incorrectly drew arrows to indicate conventional current, in contradiction to textbook B. As for Steve, there were explanatory texts and questions in an activity that can caution learners about some difficulties and misconceptions, but he did not make use of the opportunities that were afforded by the textbook. Nkatego and Robben tried to emphasise some concepts and

address some of the learners' difficulties and misconceptions similarly to the textbooks that they used. Nkatego used questions from textbook A activities to emphasise the relationship between current and resistance in a way that addresses the parallel circuit misconceptions. As for Robben, he provided explanations similar to the ones found in textbooks A and C. Furthermore, Robben emphasised the concept of voltage across cells, similar to the way in which Textbook A presented the concepts such that it becomes possible to prevent and address superposition misconceptions.

**Knowledge of conceptual teaching strategies including representations**

Textbook knowledge for this component influenced all participating teachers' knowledge which was evident when they were teaching. Victoria used the circuit diagrams evident in Textbook B, where learners were referred to the pages and used the diagrams to supplement her explanations of some concepts. However, she did not any ask questions about key concepts such as voltage or current. I speculate that textbook B was not educative because the diagrams had no explanatory texts. Also, it might be because she lacked content knowledge, as she did not do undergraduate physics as part of her qualifications and does not have experience teaching Physics at the high school level. As for Steve, he did demonstrations using instructions provided by Textbook A to present voltage across cells in electrical circuits. He used the same outline, results presentation and the textbook's conclusion. He did not ask questions beyond what was presented in the textbook, which implies that his use of demonstration was influenced only by the instructions in textbook A for the demonstrations.

Nkatego and Robben used circuit diagrams and questions from activities evident in textbooks to present electrical circuit concepts. For Nkatego, diagrams and questions

from Textbook A were used to present voltage and current in electrical circuits and the interrelatedness of the concepts. She added her own questions in addition to the questions evident in the textbook and, at times, adapted the circuit diagrams from the textbook when she wanted to emphasise a concept. For instance, she changed the values of ammeter reading for resistors in parallel circuits suggested in Textbook A to emphasise that current through resistors in parallel circuits is not necessarily divided equally. As for Robben, he used schematic and picture diagrams as presented in Textbook C. He often asked questions in Textbook C under practical activities to elicit learners' understanding of electrical circuit concepts. From Textbook A, he used schematic circuit diagrams and questions evident in activities to present voltage across resistors in a series circuit and the relation of voltage with resistance. He provided explanations similar to those in both textbooks but then went beyond what was presented in the textbooks.

### 6.3.4 Primary research question

- *How does the PCK revealed in Natural Sciences textbooks influence in-service teachers' PCK and practice in the curriculum topic of electric circuits?*

There was evidence that the participating teachers drew from the PCK revealed in textbooks to inform their PCK when teaching electric circuits in the classroom. The evidence was more obvious in the components of curricular saliency, conceptual teaching strategies, and representations and least in the components of learners' understanding of electric circuit concepts. This can be attributed to the quality of PCK revealed in textbooks. Textbooks A and C revealed *exemplary* PCK, while textbook B revealed *developing* PCK for knowledge of curricular saliency. Nkatego, Robben and Steve revealed *developing* PCK drawing from PCK revealed in textbooks A and C.

Victoria revealed basic PCK, a level lower than the textbook. The presentation of concepts, sequencing, the interrelatedness of concepts and relevance by the teachers is similar to the textbook's knowledge of curricular saliency. However, it must be noted that this does not mean that the teachers followed the exact presentation of the concepts. There were instances where teachers did not follow the sequencing of textbooks, state the relevance of concepts and explain the interrelatedness of concepts even when textbooks did so. Consequently, the teachers were allocated a level lower than the textbooks.

Regarding knowledge learners' understanding of electric circuit concepts, all textbook revealed basic PCK. Nkatego and Robben drew from the textbook and presented concepts in a such way that might prevent and address some learners' difficulties and misconceptions, similar to how Textbook A presented the content. As a result, both teachers revealed *basic* PCK for this component. On the other hand, Victoria revealed *limited* PCK, viz, a level lower than the textbook she used. When she was teaching, she realised that learners find it challenging to identify resistor connections in circuits, but she could not address the difficulty. It can be inferred that the textbook did not afford her opportunities to learn about ways to address learners' challenges, let alone make her aware of the other challenges that learners might have.

For knowledge of conceptual teaching strategies and representations, textbooks A and C revealed *developing* PCK, while Textbook B revealed *basic* PCK. Nkatego and Steve used Textbook A and revealed *basic* PCK. The two teachers use the same textbook but in different ways. Nkatego used mostly diagrams and questions from the textbook, while Steve used practical activities and did demonstrations guided by the textbook and provided explanations similar to Textbook A. As for Robben, he drew

from two textbooks to explain concepts similar to both of them while using diagrams from the textbooks. In addition, he used the questions provided in Textbook A. Textbooks A and C were allocated a level higher than the teachers, since both textbooks used multiple representations, had questions that could elicit learners' understanding of electric circuits, and provided explanations for key concepts. The teachers used one type of representation, and their teaching strategies encouraged rote learning, rather than conceptual reasoning. Victoria revealed *limited* PCK, while textbook B revealed *basic* PCK. She used one type of representation, which was a circuit diagram, but then did not use it to emphasise key concepts. Perhaps if the diagram had explanatory texts, this would guide her on using it best. The textbook did not provide explanatory texts, and teaching strategies appeared to encourage rote learning.

## 6.4 DISCUSSION OF THE FINDINGS

### 6.4.1 Textbook analysis findings

The textbook analysis's findings revealed variations in the quality of PCK components for selected textbooks. Generally, knowledge of curricular saliency is adequately presented, followed by knowledge of conceptual teaching strategies and representations and knowledge of learners' understanding of electric circuit concepts. For knowledge of curricular saliency, textbooks A and C revealed *exemplary* PCK and Textbook B revealed the *developing* PCK. The textbooks revise pre-concepts, present new concepts in relation to pre-concepts, explain the interrelatedness of concepts, and explain the relevance of learning about electric circuit concepts. These findings concur with the findings by Vojíř and Rusek (2022) and Mazibe and Rollnick (2023), who reported that textbooks represent content prescribed by curriculum, and there is an interrelatedness of the concepts. This implies that the textbooks analysed have the

potential to support teachers in developing their knowledge of the curricular saliency of electric circuits.

For knowledge of learners' understanding of electric circuit concepts, none of the textbooks revealed *limited* PCK because there are no conceptual errors and misconceptions evident in textbooks. This contrasts with the findings by Zajkov et al. (2017), which revealed that there are misconceptions evident in senior-phase physics textbooks. Furthermore, the explanations and discussion of key concepts evident in textbooks A and B do not enforce any misconceptions, which contradicts what is reported by Develi and Namdar (2019), who observed that science textbooks explain physics concepts in such a way that may enforce misconceptions. However, Textbook C states "*current is inversely proportional to resistance*", which can enforce misconceptions unintentionally. Apart from this statement, the textbook is like textbooks A and C. Although textbooks are free of misconceptions and conceptual errors, none explicitly state the learners' challenges or misconceptions of the topic; hence, the findings indicate *basic* PCK for all textbooks for this component. The reason for *basic* PCK is that there are questions, activities, and explanatory texts that can be starting points for teachers to address some of the learners' challenges with electric circuit concepts.

Regarding the use of representations to present the content, all textbooks rely on circuit diagrams, both schematic and using real pictures, and provide instructions on conducting demonstrations for key concepts in electrical circuits. Using schematic and real-picture circuit diagrams is important, given that some learners understand circuit diagrams better when presented with real pictures than they do when presented with circuit symbols (Lombard & Simayi, 2019). Furthermore, the circuit diagrams evident

in textbooks can address learners' difficulties with concepts (Preston, 2019), given that teachers use them effectively for explaining and by asking relevant questions. Textbooks A and C provide explanatory texts and suggest questions that can be asked for the circuit diagrams. As for Textbook B, the diagrams have no explanatory texts and suggest no questions. In addition to circuit diagrams and demonstrations, textbooks A and C have appropriate analogies to explain the interrelatedness of the key concepts, such as resistance and current. When used appropriately, these analogies can enhance conceptual understanding (Korganci et al., 2015). Textbook C also provides computer simulations and video links for certain concepts. As advocated for by Wong and Chu (2017), textbooks that employ multiple representations have the potential to develop a deeper understanding of the concepts. In this study, textbook B was limited to two types of representations while textbook A was limited to three and textbook C employed multiple representations.

The teaching strategies provided in the textbooks support procedural and factual knowledge as opposed to conceptual knowledge. This is evident in practical investigation activities that are suggested in the activities. In agreement with the findings by Gumilar and Ismail (2023), the activities focus on the verification of scientific knowledge where crucial skills are absent such as stating the dependent and independent variables, hypothesis, and interpretation of the results. In contrast to findings by Dunne et al. (2013), the strategies in textbooks do not support teachers in implementing conceptual teaching strategies such as inquiry-based learning to enhance conceptual reasoning of the concepts. Furthermore, there are seldom explanations in textbooks B and C to support the conceptual development of concepts. As for textbook A, the explanations provided are suitable to emphasise the fundamental concepts. Regarding using questioning to encourage conceptual

reasoning, textbook B provides no questions and textbooks A and C have questions in activities that elicit learners thinking and teachers can use to facilitate discussions. The use of questions in textbook activities concurs with the findings of Vojíř and Rusek (2022), who observed that textbooks provide questions and explanations that encourage conceptual reasoning and critical thinking. In conclusion, textbook A and C revealed *developing* PCK and Textbook B revealed *basic* PCK for knowledge of conceptual teaching strategies and representations based on the above discussion.

### 6.4.2 The influence of PCK revealed in textbooks on teachers ePCK

It is well known that learners' textbooks, even though intended for the learners, inform teachers of PCK and practice (Horsley & Sikorová, 2015). This was the case for the teachers who were involved in the current study. The collective PCK revealed in textbooks influenced teachers' PCK and practice in electric circuits during lesson preparations and teaching phases. This was more evident during teaching than during lesson preparations. When preparing for the lesson, teachers drew from PCK revealed in textbooks to inform their knowledge of conceptual teaching strategies and representations. As discussed under the secondary research question, teachers referred to textbook examples, diagrams, activities and explanations when preparing for the lesson. There was minimal influence on the component of curricular saliency and no influence on learners' understanding of electric circuit concepts. This adds to the literature on which aspects of textbooks influence teachers' PCK when preparing for lessons. It is reported that teachers use textbooks to prepare, but the way in which they use textbooks is not always specified (Vojíř & Rusek, 2021). The findings of this study indicate that PCK revealed in textbooks informed teachers PCK about how to

transform the content of electric circuits more than what concepts to teach, how to sequence the concepts, and the learners' challenges with the topic.

With regard to teaching, the influence of PCK revealed in textbooks was noticeable for all the components of PCK but not at the same level. The participating teachers drew from collective PCK revealed in textbooks to inform their knowledge of curricular saliency, conceptual teaching strategies and representations. Regarding the component of learners' understanding of electric circuit concepts, collective PCK revealed in textbooks had minimal influence on teachers' PCK. Similar findings were reported by Vollebregt et al. (2021) and C. Coetzee et al. (2022), who found that collective PCK, in their case intervention, had the least influence on teachers' knowledge of learners' understanding of science concepts. As discussed above under the primary research question, this can be attributed to the quality of PCK revealed in textbooks. The component of curricular saliency, conceptual teaching strategies and representations revealed *developing* and/ or *exemplary* PCK. The exception is textbook B, which revealed *basic* PCK for knowledge of conceptual teaching strategies. As for components of learners' understanding of electric circuit concepts, all textbooks revealed basic PCK.

Although the collective PCK revealed in textbooks influenced teachers that ePCK, this was not in the same way, even for teachers who used the same textbook. For instance, Nkatego, Robben and Steve used Textbook A, but did not draw from the textbook in the same way. Robben and Steve followed textbook sequencing and the interrelatedness of electrical circuit concepts. This concurs with the findings by Bergqvist and Chang Rundgren (2017), who reported that teachers followed the same sequencing as the one presented in textbooks. As for Nkatego, she sequenced the

concepts from current to voltage, different from how the sequencing was done in the textbook. For knowledge of conceptual teaching strategies and representations, Nkatego and Robben similarly drew from textbooks by using the activities, questions, diagrams and explanations provided in the textbooks. This is in agreement with what has been reported by teachers' use of textbooks during teaching (Bergqvist & Chang Rundgren, 2017; Sikorova, 2011). On the other hand, the influence of textbook knowledge on Steve PCK was more evident in his use of instructions from the textbooks to conduct demonstrations.

Teachers who revealed *basic* or *developing* PCK were able to utilise the opportunities provided by textbooks to develop their PCK than teachers who revealed *limited* and *basic* PCK. These findings support Winch's (2019) notion that textbooks have the potential to be powerful pedagogic tools for teachers with adequate PCK, rather than simply scripts to be used by teachers who lack PCK. Adding to the notion, it is not just any textbook but textbooks that reveal *developing* or *exemplary* PCK that has potential to support teacher learning.

## 6.5 EMERGING FINDINGS

Even though textbooks afforded teachers opportunities to develop their PCK, some teachers did not utilise those opportunities. I speculate this is because the teachers' use of textbooks is tacit; they are not aware that the PCK revealed in textbooks informs their teaching knowledge. Leshota (2020) also observed this, finding South African mathematics teachers' use of textbooks to be tacit. The author (Leshota, 2020) investigated ePCK of mathematics teachers in relation to textbook knowledge when teaching a challenging topic of functions in the context of limited resources similar to the context of this study. In addition, Leshota (2020) observed that teachers who

participated in their study overlooked the content provided in the textbooks that they used. This was the case with Nkatego and Victoria. The two teachers supplemented the textbook content with other curriculum materials provided by the curriculum advisor. The content in those curriculum materials was the same as the content provided in the textbooks, despite the teachers believing that textbooks lacked content knowledge.

It is reported that teachers who use textbooks are teachers who lack content knowledge and PCK (Orgoványi-Gajdos, 2015). In this study, it was found that teachers who have adequate PCK are those who are able to use textbooks effectively when teaching. Victoria did not utilise the opportunities afforded by textbook B. I speculate that this is because she might be lacking content knowledge and PCK as she did not take undergraduate Physics as part of her qualifications, and she does not have experience teaching physical sciences in the higher grades. She also did not seem confident when she was teaching. She often read the notes word for word. In terms of the influence of PCK revealed in textbooks with teaching experience, it was found that Steve, who has thirty years of experience teaching Natural Sciences, was influenced by PCK revealed in the textbook, similar to how Nkatego and Robben, who has less than five years of teaching Natural Sciences experience. This corroborates what Bergqvist and Chang Rundgren (2017) report, namely that PCK revealed in textbooks influences both teachers with teaching experience, as well as novice teachers. This in turn supports that textbooks are not only used by novice teachers who lack teaching experience, but experienced teachers also use textbooks.

When it comes to teachers ePCK about electric circuits, it was found that participating teachers emphasised the concept of current more than voltage. Also, the teachers did

not specify that voltage is across two points when teaching voltage across cells/resistors in electrical circuits. This has implications for learners' conceptual understanding of voltage, as it is reported that learners believe that voltage is an absolute measure at one point (Liu et al., 2022). Furthermore, the teachers did not revise what had already been learned about voltage from the previous grades and topics in the same grade and relate voltage to energy.

## 6.6 CONCLUSION

The findings of this study indicate that the collective PCK revealed in Natural Sciences learners' textbooks was translated into teachers' ePCK of electric circuits. Teachers from non-fee-paying schools with limited resources drew from the PCK revealed in textbooks to inform their knowledge of conceptual teaching strategies and representations when preparing for the lesson. When teaching, the translation of PCK revealed in textbooks was evident for all the selected knowledge components but not at the same level. The participating teacher ePCK was influenced more by the textbook knowledge of curricular saliency, conceptual teaching strategies and the use of representation to present electric circuit content. The influence of textbook knowledge of learners' understanding of electric circuit concepts on teachers' ePCK was minimal, only observed in two of the four participating teachers. This is attributed to the quality of PCK revealed in textbooks. The findings of textbook analysis regarding selected PCK components revealed that the quality of PCK revealed in textbooks varies across the components. Textbooks revealed *developing/exemplary* PCK for knowledge of curricular saliency*, developing/basic* PCK for knowledge of conceptual teaching strategies and representations and *basic* PCK for knowledge of learners' understanding of electric circuit concepts. Therefore, it is concluded that textbooks that reveal developing and exemplary PCK afford teachers from resource limited schools

the opportunities to develop their ePCK when teaching electric circuits to Grade Nine learners. Also, teachers with adequate content knowledge and PCK used the opportunities afforded by the textbooks better than those teachers who revealed limited PCK. This implies that teachers ought to have adequate content knowledge and PCK to utilise the opportunities afforded by the textbooks.

## 6.7 PERSONAL REFLECTION

Generally, PCK authors in science education associate the construct of PCK with teachers, not with curriculum materials such as textbooks. In this study, I argued that PCK can be associated with textbooks. This is because PCK is a knowledge base associated with transforming content knowledge in a way that learners can comprehend (Shulman, 1986), and textbooks present the prescribed content for learners' comprehension. Hence, I investigated the PCK revealed in textbooks and the extent to which it impacts teachers' ePCK when teaching electric circuits.

I started by analysing textbooks using selected PCK components as discussed in Chapter 4. It was more challenging to analyse the knowledge of learners' understanding of science concepts revealed in textbooks compared to the knowledge of curricular saliency, representation, and conceptual teaching strategies. This is because, for the two components, it is clear what I should look for, and it was easy to adapt existing rubrics meant to assess teachers' PCK. As for knowledge of learners understanding, the challenge lay in the fact that because the textbooks do not necessarily state that this is a misconception or that learners have difficulties with these concepts. However, the textbook may emphasise key concepts and draw attention to learners by using boxes titled *"tips/ take note*" for concepts that learners have misconceptions/ difficulties. This worked for Textbook B and C, as they make

use of such boxes, but for Textbook A, there are no such boxes. It was consulting with my supervisors and literature about textbook analysis that helped me with regards to what aspects to look for when analysing learners' understanding of science concepts. Concerning the literature on textbook analysis, it was challenging to relate this to the current study because not many authors analysed textbooks from the perspective of PCK. However, in the end, I managed to develop a rubric to analyse all the components.

Analysing textbooks afforded me the opportunity to engage with the textbooks. During my undergraduate studies, I was never taught about how to analyse textbooks and how to best utilise opportunities afforded by textbooks when teaching. Also, during professional development workshops, we were never taught about how to best use textbooks and other curriculum materials, highlighting their strengths and weaknesses. It was in this study that I learned how to analyse textbooks and make the most of the opportunities that they afford to develop my PCK. I now use the rubric from this study to analyse textbooks for other topics and subjects. Where I find out that the textbook is limited, I supplement it with another textbook and other curriculum materials. For instance, for Grade 10 and 11 Physical Sciences, learners use two types of textbooks due to a shortage. I go through the content in those textbooks and recommended either one or both of them for specific topics depending on the quality of PCK revealed in those textbooks.

Regarding the influence of PCK revealed in textbooks on teachers' ePCK, I found it interesting that teachers used the questions and diagrams in activities to teach, and not for assessment purposes at the end of the lesson, as suggested in the textbooks. This is when learners seemed interested and participated when the teacher asked

questions. In the case of Nkatego, she adapted some of those questions to emphasise concepts that learners find challenging. It was notable that activities can form a relevant part of teaching strategy. I now use the activities in textbooks mostly when teaching and I create worksheets and rely on past question papers for assessment. Previously, I only used the activities for assessment purposes. The other thing that I found interesting was when Robben used practical investigation guidelines to inform his PCK and used that when he was teaching even though he did not do the actual practical. He made learners aware that the brightness of the bulbs depends on the voltage across the power source. In the case of Steve, it became clear that the instructions provided by the textbook on how to conduct a demonstration were limited as they did not have questions that could enhance conceptual reasoning. Learners seemed to understand even after the teacher taught.

After classroom observations, it was necessary to return to the analysis of the textbook chapter, because my perspective on some aspects of textbooks changed after seeing how teachers used it. Overall, the analysis of textbooks and how the PCK revealed in textbooks impacted teachers' ePCK contributed to my development of PCK beyond the scope of this study.

## 6.8 LIMITATIONS OF THIS STUDY

As with other educational research, the first limitation of this study concerns the research design. This study adopted a case study research design, which involved only three commonly used textbooks and four teachers from public non-fee-paying secondary schools with limited resources in Sekhukhune East District in Limpopo Province. For this reason, the findings of this study cannot be generalised to the entire population of South African science teachers who use textbooks as part of curriculum

materials when preparing for lessons and teaching in classrooms. However, the findings can contribute towards a theory (Cohen et al., 2018) about how science teachers in public non-fee-paying schools with limited resources use textbooks for teaching science from the perspective of PCK.

The second limitation is the data collection methods. Only interviews were used to capture teachers' PCK about lesson preparations. It would be better if other data sources, such as lesson plans/preparations and maybe questionnaires, were used to investigate the influence of PCK revealed in textbooks on the lesson preparations of teachers. The third limitation is regarding the interpretation of data. In order to minimise researcher bias, I adhered to the rubrics used, which were adapted from existing literature and confirmed by the supervisor.

## 6.9 RECOMMENDATIONS OF THIS STUDY

The findings of this study indicate that textbooks can be analysed using PCK components so as to examine whether they can contribute to the development of teachers' PCK and practice in electric circuits. It is recommended that textbook analysis be done for other challenging physical sciences topics in the senior phase (Grades 7 – 9) for Natural Sciences. It is not possible to infer that the textbooks will reveal the same PCK for other topics, given that PCK is topic-specific (Mavhunga & Rollnick, 2013). In addition to textbook analysis from the perspective of PCK, it is recommended that researchers investigate how content is translated from professional knowledge bases to collective PCK, as revealed in the textbooks using the RCM of PCK. This comes after observing that some activities in textbooks that were intended for assessment purposes were used as part of teaching strategies to present the content.

The findings of this study also indicate that the quality of PCK revealed in textbooks was higher or at the same level as that of teachers' ePCK. This can be ascribed to the study context, where the teachers who participated in this study were from public non-fee-paying schools with limited resources. As a result, it was not possible to do the practical investigation activities and demonstrations guided by the textbooks due to a lack of facilities and resources. In the interview, the teachers indicated that demonstrations are best suited to teach electric circuit concepts because learners get to observe what you are talking about. However, due to challenges such as lack of facilities and resources, that was not possible. The context of the study had a great impact on teachers' use of textbooks mostly for the component of conceptual teaching strategies, representations and learners' understanding of science concepts. For the component of curricular saliency, it remains unclear as to why the textbook did not have an impact. Therefore, it is recommended that researchers investigate the pedagogical factors for the translation of PCK revealed in textbooks on teachers' ePCK for all the PCK components selected for this study in the context of limited resources and schools with sufficient resources. Furthermore, it is recommended that the research on the influence of PCK revealed in textbooks on teachers' PCK includes teachers' content knowledge of the subject. The participating teachers' content knowledge seemed limited when it came to the content presented in the textbooks. All teachers did not relate the concept of voltage to energy. Also, the teachers did not emphasise the concept of energy in electrical circuits. Learners are taught about the law of conservation of energy in the previous grades.

Regarding teaching science using textbooks, it is recommended that teacher professional development programs and initial teacher education train teachers on how to best utilise the affordances provided by the textbooks when it comes to

teaching. This is more important for teachers who teach in a limited resource context, like those who participated in this study because the textbook is the main curriculum material used. Additionally, this recommendation comes after finding out that teachers who revealed *limited* or *basic* PCK did not utilise the opportunities afforded by the textbooks. While context might play a role when it comes to doing demonstrations guided by the textbook, some affordances provided by the textbook apply to any context, resourced and not resourced. For instance, interrelating key concepts or using questions provided by textbooks enhances conceptual development and facilitates discussions.

Lastly, teachers should be encouraged to analyse textbooks and take into account how it present the content. This is essential because learners in public non-fee-paying schools rely only on textbooks as the only source of information to learn the prescribed content. This bring me to the last recommendation, future studies can focus on developing and validating rubrics that measure the PCK revealed in textbooks. This comes after observing that the use of two rubrics, one for PCK revealed in textbooks and one for teacher enacted PCK allowed for exploration of how content presented in textbooks impact teachers classroom practice. The rubric for analysing textbooks can also help teachers to analyse textbook which will help with engaging with the content presented in textbooks.

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## APPENDICES

## APPENDIX I: PCK rubric for assessing PCK revealed in textbooks

| PCK components | Limited | Basic | Developing | Exemplary |
|---|---|---|---|---|
| **Knowledge of curricular saliency** | • There is no awareness of pre-concepts by the textbook authors.<br>• The new concepts are not developed from or linked with corresponding pre-concepts.<br>• The textbook author's sequencing of concepts is illogical, and the interrelatedness of the concepts is not explained.<br>• The relevance of the concepts is not explicit.<br>• The textbook authors do not discuss all the concepts prescribed in the curriculum. | • There is seldom awareness of pre-concepts by the textbook authors.<br>• A few of the new concepts are developed from or linked with corresponding pre-concepts.<br>• The sequencing of concepts is illogical, and the interrelatedness of concepts is seldom explained.<br>• The relevance of the concepts doesnot support conceptual understanding.<br>• The textbook authors discuss only a few concepts prescribed in the | • There is awareness of someof the pre-conceptsby the textbook authors.<br>• Most of the concepts are developed from or linked with corresponding pre-concepts.<br>• The sequencing of concepts is logical, and the interrelatedness of concepts is often explained.<br>• The relevance ofthe concepts involves scaffolding towards generic concepts.<br>• The textbook authors discuss most of the | • There is awareness of most of the pre-concepts by the textbook authors.<br>• The new concepts are developed from or linked with corresponding pre-concepts.<br>• The sequencing of concepts is logical, and the interrelatedness of the concepts is explained.<br>• The relevance of the concepts reveals scaffolding towards specific concepts.<br>• The textbook authors discuss all the prescribed concepts inthe curriculum. |

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| | | curriculum. | concepts prescribed in the curriculum. | |
| **Knowledge of learners understanding of science concepts** | • No understanding of learners' common difficulties and misconceptions evident in textbooks.<br>• The statements provided in textbooks do not caution learners about common misconceptions and difficulties.<br>• Textbook authors do not address learners' misconceptions and challenges of key concepts.<br>• The textbook reveals misconceptions and conceptual errors. | • A narrow understanding of learners' common difficulties or misconceptions is evident in textbooks.<br>• The statements provided seldom caution learners about common misconceptions and difficulties.<br>• Textbook authors address some of the learners' challenges with key concepts by providing standardized phrases, e.g "*current is the same at all points in series"*<br>• The explanations | • There is an adequate understanding of learners' common difficulties and/ or misconceptions evident intextbooks.<br>• The statements provided caution learners about some of the common misconceptions and difficulties.<br>• The textbook authors address some of the learners' challenges and provide explanations.<br>• The explanations provided in textbooks do not enforce misconceptions. | • A sophisticated understanding of learners' common difficulties and misconceptions is evident intextbooks.<br>• The statements provided caution learners' about common misconceptions and difficulties.<br>• Textbook authors address most of the learners' challenges, starting from gatekeeping concepts to expanding on explanations.<br>• The explanations provided have no conceptual errors/misconceptions and do not enforce |

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| | | provided in textbooks can enforce misconceptions. | | any misconceptions. |
| **Knowledge of conceptual teaching strategies and representations** | • The questions evident in the textbook do not support conceptual development<br>• There are no explanations and discussions for important and challenging concepts<br>• The representations do not have explanatory texts and are specific to important and challenging concepts<br>• The teaching strategies are technical and do not encourage conceptual reasoning | • The questions evident in textbooks seldom support conceptual development<br>• There are seldom explanations and discussions<br>• There are few representations with explanatory texts<br>• The teaching strategies support rote learning, not conceptual reasoning and critical thinking | • The questions evident in the textbook are sufficient to support conceptual development<br>• There are sufficient explanations and discussions provided<br>• There are various representations with explanatory texts and discussions<br>• The teaching strategy sufficiently supports conceptual understanding while encouraging rote learning | • The questions evident in the textbook support conceptual development and encourage critical thinking<br>• There are explanations and discussions provided appropriately<br>• There are multiple uses of representations for important and challenging concepts with explanatory texts and discussions<br>• The teaching strategies suggested show an attempt to work towards inquiry and support conceptual reasoning and critical thinking |

**APPENDIX II: PCK rubric for assessing teachers enacted PCK**

| PCK components | Limited | Basic | Developing | Exemplary |
|---|---|---|---|---|
| **Knowledge of curricular saliency** | • The teacher does not elicit knowledge of learners' pre-concepts.<br>• The new concepts are not developed from or linked with corresponding pre-concepts.<br>• The sequencing of concepts is illogical, and the interrelatedness of the concepts is not explained.<br>• The relevance of the concepts is not explicit.<br>• The teacher does not discuss all the concepts prescribed in the curriculum. | • The teacher elicits knowledge of some of the learner's pre-concepts.<br>• A few of the new concepts are developed from or linked with corresponding pre-concepts.<br>• The sequencing of concepts is illogical, and the interrelatedness of concepts is seldom explained.<br>• The relevance of concepts does not support conceptual understanding.<br>• The teacher discusses only a few of the concepts that are prescribed in the curriculum. | • The teacher elicits knowledge of most of the learners' pre-concepts.<br>• Most of the concepts are developed from or linked with corresponding pre-concepts.<br>• There is logical sequencing of concepts, and the interrelatedness is often explained.<br>• The relevance of the concepts does not involve scaffolding towards generic concepts.<br>• The teacher discusses most of the prescribed concepts in the curriculum. | • The teacher elicits knowledge of all learners' pre-concepts at appropriate phases of the lessons.<br>• The new concepts are developed from or linked with corresponding pre-concepts.<br>• There is logical sequencing of concepts, and the interconnectedness of the concepts is explained.<br>• The relevance of the concepts reveals scaffolding towards specific concepts.<br>• The teacher discusses all the prescribed concepts in the curriculum. |

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| **Knowledge of learners understanding of scinece concepts** | • No facilitation of discussions that uncover learners' understanding of concepts and difficulties.<br>• The teacher makes no effort to help learners understand difficult concepts.<br>• Does not pay attention to existing possible misconceptions or difficulties that emerge during the lesson.<br>• No understanding of learners' common difficulties and misconceptions. | • Discussions that uncover learners' understanding of concepts and difficulties are seldom facilitated.<br>• The teacher attempts to address difficult concepts by providing standardized phrases, e.g., "*current is the same in a series circuit.*"<br>• The teacher pays attention to a few known misconceptions and difficulties that emerge but does not address the misconceptions.<br>• Narrow understanding of learners' common difficulties and misconceptions. | • The teacher facilitates cognitive discussions that uncover learners' understanding of some concepts and difficulties.<br>• The teacher addresses some areas of difficulties while expanding on explanations.<br>• The teacher pays attention to three or more known misconceptions and difficulties that emerge but does not adequately address them.<br>• Adequate understanding of learners' common difficulties and misconceptions. | • The teacher facilitates cognitive discussions that uncover learners' understanding of most concepts and difficulties.<br>• The teacher addresses most areas of difficulties, starting from gatekeeping concepts and expanding on explanations.<br>• The teacher pays attention to most or all known misconceptions and difficulties that emerge and uses a variety of representations and teaching strategies to address them.<br>• Sophisticated understanding of learners' common difficulties and misconceptions. |

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| **Knowledge of conceptual teaching strategies and representations** | • Questions elicit yes/no answers, and the teacher answers their questions before the learners' attempt.<br>• There are no discussions for important and difficult concepts.<br>• There are no explanations.<br>• The teaching strategies support rote learning and algorithms rather than conceptual understanding.<br>• The representations used by the teacher are vague and not used to explain important and difficult concepts. | • Questions asked mostly require rote learning, and the teacher answers their own questions after one or two attempts by the learners.<br>• There are seldom discussions for important and difficult concepts.<br>• Explanations are seldom provided.<br>• The strategies seldom support rote learning rather than conceptual understanding.<br>• The representations (visual and/ or symbolic) used by the teacher are insufficient, and they are used to explain a few important and difficult concepts. | • Most questions do not require rote learning, and the teacher involves the learners in the lesson.<br>• There are sufficient discussions for important and difficult concepts.<br>• Explanations are sufficiently provided.<br>• The strategies sufficiently support conceptual understanding while encouraging rote learning.<br>• There is adequate use of representations to explain important and difficult concepts. | • The teacher asks questions to elicit learner thinking that requires conceptual reasoning and learners are engaged in discussions.<br>• Explanations are appropriately provided.<br>• The strategies work towards inquiry and the nature of science to support conceptual understanding of important and difficult concepts.<br>• There is extensive use of representations (visual and symbolic/ graphical/ pictorial/ diagrammatical) to enforce important and difficult concepts. |

## APPENDIX III: Letters of permission

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

CONFIDENTIAL

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

**Maponya CR**
P.O BOX 92
Makgwaneng
Marble Hall
0450

**RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH**

1. The above bears reference.

2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal: **"Exploring the influence of textbooks on teachers' pedagogical content knowledge (PCK) and practice in electric circuits"**

3.The following conditions should be considered:

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

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

3.3 The conduct of research should not in anyhow disrupt the academic programs at the schools.

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

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

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



Cnr 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X 9489, Polokwane, 0700
Tel:015 290 7600/ 7702 Fax 086 218 0560

4 Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.

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

Best wishes.

01/08/2023

**Mashaba KM**
**DDG: CORPORATE SERVICES**

**Date**



Cnr 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X 9489, Polokwane, 0700
Tel:015 290 7600/ 7702 Fax 086 218 0560

**APPENDIX IV: Letters of Consent**


**Department of Science, Mathematics and Technology Education**

**Mr CR Maponya**

**Seokodibeng stand number 92**

**Moroke 1129, Burgesfort**

**crousemaponya@gmail.com**

**072 301 9923**

**10 August 2023**

The Principal

XXXXX Secondary School

Burgesfort

1154

**RE: Request for Permission to Conduct Research at Phafane Secondary School**

Dear Sir/Madam

I am a Master's in Education student at the University of Pretoria. The title of my study towards Master's degree is "**Exploring the influence of textbooks on teachers Pedagogical Content Knowledge (PCK) and practice in electric circuits**". The aim of my study is to investigate the impact of natural sciences textbooks knowledge of teaching (referred to as PCK) on teachers knowledge of teaching and practice in the curriculum topic of electric circuits at grade 9 level. I am working under the supervision of Dr Philip Mirkin as supervisor and Dr Corene

Coetzee as co-supervisor from the Department of Science, Mathematics and Technology Education at the University of Pretoria.

I kindly ask if you would grant me permission to conduct research in your school with your Grade 9 Natural Science teachers and their learners. The teachers will be requested to be observed teaching the topic of electric circuits to the learners in the classroom and participate in an interview. The learners will be requested to fill a consent form that grant me permission to be present when the teacher teach electric circuits. No data will be collected from the learners.

**Procedures**

Regarding lesson observations, I will observe two lessons for maximum of 120 minutes where the teacher will be teaching the concepts of series and parallel circuits under the topic of electric circuits. The observed lessons will be video recorded for data purposes. Learner's faces will not be shown in the video, the camera will focus only on the teacher, and the videos will be watched by only myself to validate the data. The lesson observations will not interfere with normal school days in any way. Teachers will be expected to teach the topic the way they would teach it in my absence. After lesson observations, I will conduct an interview which will take a minimum of 20 minutes to maximum of 60 minutes. The interview will be divided into two parts, video-stimulated interview and semi-structured interview. The video-stimulated recall interview is about reflection on the lesson while the semi-structured interview is about how teachers plan to teach electric circuits using a textbook. The interviews will be audio recorded for the purpose of data too. Interviews will take place at a teachers' preferred place and time in a way that does not interfere with their working hours.

**Ethical principles**

- Informed consent will be in place, meaning, all the participants involved in this study will be informed about the purpose and the process of this study. Furthermore, participants will give consent for their participation in the study.
- I am at liberty to contact the researcher at any time if I have any questions or concerns about the study.

- I understand that all information gathered about school or teachers in this study will be kept confidential. **No school names, participant names, or personal information will be reported in my research.**
- I understand that the findings of this study will be disseminated within academic contexts.

The teachers who will participate in this study will be asked for permission by the researcher to make video recordings of lesson observations and audio recordings of the interview. The purpose thereof is to make transcription of data valid and authentic. The recordings will be safely kept at the University of Pretoria. Only my supervisor and I that will have access to the recordings. All data collected will only be used for academic purposes.

I have carefully studied the above and understand this agreement. I thus freely consent and voluntarily agree that my school acts as a research site for this study as described above.

Name of the Principal: _____

Contact numbers:

_____

Email: _____

Signature: _____ Date:

_____

**Yours faithfully**


Mr Crouse Maponya

Principal Researcher

crousemaponya@gmail.com

072 301 9923

_____*CR Maponya*_____

Dr Philip Mirkin

Supervisor

Philip.mirkin@up.ac.za

012 420 5663

____ ____

**Department of Science, Mathematics and Technology Education**

**RE: Teacher Informed consent to participate in research study.**

Dear Teacher

I am a Master's in Education student at the University of Pretoria. The title of my study towards Master's degree is "**Exploring the influence of textbooks on teachers Pedagogical Content Knowledge (PCK) and practice in electric circuits**". The aim of my study is to investigate the impact of natural sciences textbooks knowledge of teaching (referred to as PCK) on teachers knowledge of teaching and practice in the curriculum topic of electric circuits at grade 9 level. I am working under the supervision of Dr Philip Mirkin as supervisor and Dr Corene Coetzee as co-supervisor from the Department of Science, Mathematics and Technology Education at the University of Pretoria.

As one of the participants, I kindly invite you to participate in the study. There are two parts to this research, lesson observation and interview.

**Procedures**

Regarding lesson observations, I will need to observe two lessons where you will be teaching the concepts of series and parallel circuits under the topic of electric circuits. The maximum time for lesson observations will be 120 minutes. I will video record the observed lessons for data purposes. During the lessons, I will not interfere in any way. You will be expected to teach the topic the way you would teach it in my absence. After lesson observations, I will conduct an interview which will take a minimum of 20 minutes to maximum of 60 minutes. The interview will be divided into two, video-stimulated interview and semi-structured interview. The video-stimulated recall interview is about reflection on the lesson while the semi-structured interview is about how you plan to teach electric circuits using a textbook. The interviews will be

audio recorded for the purpose of data too. Interviews will take place at your preferred place and time that suits you.

**Conditions of participation**

- I understand that teachers even though they have agreed to participate are free to withdraw their consent and discontinue their participation at any time without negative consequences or penalty. They may do so by informing any of the researcher verbally, in writing or by telephone using the contact details provided for this purpose.
- I am at liberty to contact the researcher at any time if I have any questions or concerns about the study.
- I understand that all information gathered about myself or school in this study will be kept confidential. **No participant names or personal information will be reported in my research.**
- I understand that the findings of this study will be disseminated within academic contexts.

In participating in this research study, you will be asked for permission by the researcher to make video recordings of lesson observations and audio recordings of the interview. The purpose thereof is to make transcription of data valid and authentic. The recordings will be safely kept at the University of Pretoria. Only my supervisor and I that will have access to the recordings. All data collected will only be used for academic purposes.

You may ask questions before or during the time of participation. If you have any concerns regarding the data collection procedures, please notify me or my supervisor. As a participant, you will have the opportunity to access and verify the recorded views and the transcriptions of interviews made in case there is a need to do so.

I have carefully studied the above and understand this agreement. I thus freely consent and voluntarily agree to participate in this study.

Name and surname:

_____

Contact number:

_____

Signature: _____ Date:

_____

**Yours faithfully**


Mr Crouse Maponya

Principal Researcher

crousemaponya@gmail.com

072 301 9923

_____*CR Maponya*_____

Modiadie Secondary School

Dr Philip Mirkin

Supervisor

Philip.mirkin@up.ac.za

012 420 5663

_____ _____

University of Pretoria


UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

**Department of Science, Mathematics and Technology Education**

Dear Parent/ Guardian

**RE: Request to allow child to be present in a lesson that will be observed and video recorded**

I am a Master's in Education student at the University of Pretoria. The title of my study towards Master's degree is "**Exploring the influence of textbooks on teachers Pedagogical Content Knowledge (PCK) and practice in electric circuits**". The aim of my study is to investigate the impact of natural sciences textbooks knowledge of teaching (referred to as PCK) on teachers' knowledge of teaching (PCK) and practice in the

curriculum topic of electric circuits at grade 9 level. I am working under the supervision of Dr Philip Mirkin as supervisor and Dr Corene Coetzee as co-supervisor from the Department of Science, Mathematics and Technology Education at the University of Pretoria.

One of the data collection methods is lesson observation where the teacher will be observed teaching the topic of electric circuits for two lessons. The observed lessons will be video recorded for data purposes. I will not interfere with the lesson in any way, the teacher will be expected to teach the way they would in my absence. Your child will be one of the learners that will be present during video recording of the lesson. I kindly ask for your permission to have your child present during the lessons. Your child face will not be shown in the video and if the child turns and face camera, I will block his/her face to protect his/her identity. The only data that will be collected is from the teacher. The purpose of video recordings is to make transcription of data valid and authentic. The recordings will be safely kept at the University of Pretoria. Only my supervisor and I that will have access to the recordings. All data collected will only be used for academic purposes.

**Conditions of participation**

- I understand that even though I have agreed that my child can participate in the study, I am free to withdraw consent at any moment. I can do so by informing the researcher verbally, in writing or by telephone using the contact details provided for this purpose.
- I am at liberty to contact the researcher at any time if I have any questions or concerns about the study.
- I understand that all information gathered in this study will be kept confidential. **No school names, participant names or personal information will be reported in my research.**
- If I do not grant my child permission to partake in the study, then he or she will not miss out on the lesson.
- I understand that the findings of this study will be disseminated within academic contexts.

I have carefully studied the above and understand this agreement. I thus freely consent and voluntarily agree that my child participate in this study.

Name and surname: _____

Contact number: _____

Signature: _____ Date: _____

**Yours faithfully**


| | |
|---|---|
| Mr Crouse Maponya | Dr Philip Mirkin |
| Principal Researcher | Supervisor |
| crousemaponya@gmail.com | Philip.mirkin@up.ac.za |
| 072 301 9923 | 012 420 5663 |

_____CR Maponya_____ _____ ____

Modiadie Secondary School University of Pretoria


**Department of Science, Mathematics and Technology Education**

Dear Grade 9 Learner

**RE: Request to give consent to be present in a lesson that will be observed and video recorded**

I am a Master's in Education student at the University of Pretoria. The title of my study towards Master's degree is "**Exploring the influence of textbooks on teachers Pedagogical Content Knowledge (PCK) and practice in electric circuits**". The aim of my study is to investigate the impact of natural sciences textbooks knowledge of teaching (referred to as PCK) on teachers' knowledge of teaching (PCK) and practice in the curriculum topic of electric circuits at grade 9 level. I am working under the supervision of Dr Philip Mirkin as supervisor and Dr Corene Coetzee as co-supervisor from the Department of Science, Mathematics and Technology Education at the University of Pretoria.

One of the data collection methods is lesson observation where the teacher will be observed, and video recorded teaching the topic of electric circuits for two lessons. I hereby ask for permission to be present during the lessons. I will not interfere with the lesson in any way, the teacher will be expected to teach the way they would in my absence. The learners' face will not be shown in the video and if the learner turns and face camera, I will block his/her face to protect his/her identity. The only data that will be collected is from the teacher. The purpose of video recordings is to make transcription of data valid and authentic. The

recordings will be safely kept at the University of Pretoria. Only my supervisor and I that will have access to the recordings. All data collected will only be used for academic purposes.

**Conditions of participation**

- I understand that even though I have agreed to participate in the study, I am free to withdraw consent at any moment. I can do so by informing the researcher verbally, in writing or by telephone using the contact details provided for this purpose.
- I am at liberty to contact the researcher at any time if I have any questions or concerns about the study.
- I understand that all information gathered in this study will be kept confidential. **No school names, participant names or personal information will be reported in my research.**
- If I do not grant my permission to partake in the study, then I will not miss out on the lesson. Instead, they will put me at the back where the camera will not show me at all.
- I understand that the findings of this study will be disseminated within academic contexts.

I have carefully studied the above and understand this agreement. I thus freely consent and voluntarily agree to participate in this study.

Name and surname: _____

Signature: _____ Date: _____

**Yours faithfully**


| | |
|---|---|
| Mr Crouse Maponya | Dr Philip Mirkin |
| Principal Researcher | Supervisor |
| crousemaponya@gmail.com | Philip.mirkin@up.ac.za |
| 072 301 9923 | 012 420 5663 |
| _____*CR Maponya*_____ | _____ _____ |
| Modiadie Secondary School | University of Pretoria |