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Electrical Technology teachers' pedagogical content knowledge of three-phase induction motors

by

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Submitted in fulfilment of the requirements for the degree

Master of Education

Faculty of Education

at the

UNIVERSITY OF PRETORIA

Supervisor: Prof. WJ Rauscher

March 2024

Declaration

I declare that the dissertation titled **"Electrical Technology Teachers' Pedagogical Content Knowledge of three-phase Induction Motors"** which I hereby submit for the degree Master of Education at the University of Pretoria, is my work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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INVESTIGATOR	Mr Shane Maelane
DEPARTMENT	Science Mathematics and Technology Education
APPROVAL TO COMMENCE STUDY	24 April 2023
DATE OF CLEARANCE CERTIFICATE	18 March 2024

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Dedication

I dedicate this research to my mother, Rosemary Maelane, and my siblings, Marvin, Simon, Edward, Dimakatso, and Kgaogelo.

Acknowledgements

I would like to thank the following people who have helped me undertake this research:

My supervisor Prof. WJ Rauscher, for his enthusiasm for the dissertation, for his support, encouragement, and patience;

My participants for whom without, this was not going to become possible;

My editors, Mzansi Writers for their thorough and detailed attention;

The City of Peterborough Academy, for affording me time to work on my dissertation after I just arrived in the UK;

My family for believing in me;

Last but not least, my beloved Fonanki for her tireless support, patience, and motivation.

Abstract

The quality of teaching significantly affects learners' ability to learn. Sound Pedagogical Content Knowledge (PCK) is foundational to good teaching and in the Technology classroom, this is associated with high-level technology skills. Curriculum changes may add to the difficulties that these teachers experience because of unfamiliarity with the new content, and possibly pre-existing PCK deficiencies. Given the paucity of research on PCK in the electrical technology classroom, this qualitative study was designed to investigate electrical technology teachers' PCK of three-phase induction motors to improve our understanding of their personal Pedagogical Content Knowledge (pPCK) and enacted Pedagogical Content Knowledge (ePCK). A better understanding of these teachers' PCK may provide clarity as to the need for professional development in this area.

Following the interpretivist paradigm and a single case study design, interviews were conducted to provide rich descriptions of Grade 12 electrical technology teachers' pPCK, using adapted Content Representations (CoRes). Classroom observations provided information about their ePCK. Six Grade 12 electrical technology teachers were purposively and conveniently selected as participants in the study. The adapted Refined Consensus Model (RCM) was used as the framework that guided the analysis of the two manifestations of PCK. The focus was on learners' prior knowledge, including misconceptions, curricular saliency, what is difficult to teach, representations, such as analogies, and conceptual teaching strategies.

The findings of this study indicate that electrical technology teachers' PCK falls short of expectations and requires improvement. This finding was consistent for both pPCK and ePCK. A comparison of their pPCK and their ePCK showed that what they espouse theoretically is not necessarily made manifest in the classroom. Further research in this area should perhaps include different contexts, focusing on different topics, as well as associated documentation.

Keywords:

Pedagogical Content Knowledge, personal Pedagogical Content Knowledge, enacted Pedagogical Content Knowledge, Refined Consensus Model, and curricular saliency.

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List of abbreviations

PCK	Pedagogical Content Knowledge
PPCK	Personal Pedagogical Content Knowledge
EPCK	Enacted Pedagogical Content Knowledge
RCM	Refined consensus model
DoBE	Department of Basic Education
FET	Further education and training
CAPS	Curriculum assessment policy statement
CDE	Centre for development and enterprise
JTB	Justified true belief
PLC	Professional learning communities
CoRe	Content Representation

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1. CHAPTER ONE: ORIENTATION OF THE STUDY

1.1. OVERVIEW OF THE CHAPTER

In Chapter 1, an overview and orientation of the study are presented. The introduction and background section emphasises the importance of teachers' Pedagogical Content Knowledge (PCK). It is argued that if a teacher's PCK is deficient, the pedagogy and teaching content may not be up to standard, which can, among other things, lead to poor teaching quality and misconceptions about electrical concepts in a subject such as Electrical Technology. The introduction and background are followed by the research problem, purpose statement, rationale, and significance. In addition, the research questions that guided the study, assumptions, research design, and methodology are addressed. The chapter also outlines the ideas employed, a summary of the conceptual framework that guided this research, concept clarification and concludes with the outline and organisation of the study and a summary of the chapter.

1.2. INTRODUCTION AND BACKGROUND

Numerous scholars believe that the quality of teaching learners receive directly impacts their ability to learn (Darling-Hammond, 2017; Khosa, 2014). Ma (1999) and Bukova-Güzel (2010) discovered that a teacher's ability to assist learners in understanding a subject could not exceed the teacher's understanding of that subject. Most people agree that successful teaching requires a sound understanding of the subject (Ball et al., 2008). There is also universal agreement that teachers' domain-specific proficiency is an essential component of high-quality education (Krauss et al., 2008). This domain-specific knowledge is known as Pedagogical Content Knowledge (PCK). PCK is important in a teacher's professional growth; it is described as the knowledge that is uniquely designed for preparing and teaching a specific subject, and that knowledge is exclusive to that subject (Shulman, 1986). A report by Carlson et al. (2019) indicates that PCK is subject-specific and that the preparations, knowledge, and skills needed to teach a particular topic will vary depending on the topic. Shulman (1987) adds that PCK outlines the characteristics of different types of knowledge needed for teaching.

South Africa has a shortage of high-level technological skills, which is a consequence of poor teaching, as most qualified teachers lack PCK for quality teaching (Hofmeyer, 2015). Such technological skills include skills in school subjects, such as civil, mechanical, and electrical technology. According to a 2011 CDE report by Bernstein (2011), South Africa was producing just one-third of the country's required 25,000 new teachers each year, with a particular shortage in critical areas such as mathematics, science, business, and technology. This low teacher output exacerbates the already high teacher-learner ratio, making it difficult to provide individualised attention and effective instruction. Thus, leading to learners having misconceptions about electrical concepts in high schools, colleges and beyond (Afra et al., 2009).

Electrical technology teachers' PCK is a crucial factor in determining the standard of teaching and in guaranteeing learners' success in the field. Previous studies have examined several facets of pedagogical topic understanding, offering insightful information on instructional approaches and techniques (Prastyaningrum & Pratama, 2019). This study focuses on the PCK of three-phase induction motors among Further Education and Training (FET) teachers, a critical topic in the teaching of electrical technology.

1.3. RESEARCH PROBLEM

Teachers' poor grasp of PCK results in learners' ill preparation for examinations, tertiary institutions, and beyond in technical skills (Jeschke et al., 2021). In South Africa, changes in the electrical technology curriculum, implemented by the Department of Basic Education (DoBE) (2014), may exacerbate this problem, as some topics need to be taught differently because new content was added to the topics. These changes in the CAPS document may result in planning, preparation, and presentation problems for electrical technology teachers, as they are unfamiliar with the new content. This does not bode well for these teachers, who may already have a PCK deficit. This study focused on one of these curriculum changes, namely the changes in three-phase induction motors, to improve our understanding of electrical technology teachers' PCK on this topic.

1.4. PURPOSE STATEMENT

Numerous studies have examined teachers' PCK over the years, examining a variety of topics, including its development, impact on learner learning outcomes, and strategies for improving teachers' expertise in this field (Ferdiansyah et al., 2022; Kim, 2021; Rollnick, 2017). However, research on ways to improve electrical technology teachers' PCK is limited (Azam, 2020; Gunstone et al., 2009; Kotoka, 2018; Voogt et al., 2013). Given the scarcity of research on PCK in the electrical technology classroom, the purpose of this qualitative study was to investigate electrical technology teachers' PCK of three-phase induction motors to better understand their personal Pedagogical Content Knowledge (pPCK) and enacted Pedagogical Content Knowledge (ePCK). A greater knowledge of these teachers' PCK may help to clarify the need for professional development in this area.

1.5. RATIONALE AND SIGNIFICANCE

Shulman (1986) argues that PCK, which combines pedagogical comprehension and subject knowledge, is essential for teaching expertise. Research on electrical technology teachers' PCK of three-phase induction motors can reveal crucial teaching knowledge and skills that might not otherwise be apparent. To improve teaching quality, teachers can create tailored interventions by identifying specific areas which are either strong or weak in PCK (Smith & Neale, 1989).

Park and Oliver (2008) contend that PCK is a dynamic and changing concept that is affected by elements, such as the teacher's background and the classroom environment. Therefore, investigating electrical technology teachers' PCK of three-phase induction motors may enhance our understanding of how to employ various strategies to enhance teaching and learning. This knowledge can be helpful in teacher development programs, for example, the inclusion of context-sensitive techniques for fostering PCK.

1.6. RESEARCH QUESTIONS

1.6.1. Main Question

How do electrical technology teachers' pPCK and ePCK of three-phase induction motors manifest in the classroom?

1.6.2. Sub-questions

- ❖ How can electrical technology teachers' pPCK of three-phase induction motors be described?
- ❖ How can electrical technology teachers' ePCK of three-phase induction motors be described?
- ❖ How do electrical technology teachers' pPCK and ePCK of three-phase motors compare?

1.7. ASSUMPTIONS

Based on the available research on PCK for technology, the following assumptions were made:

- ❖ Written CoRes may describe a teacher's tacit knowledge (PCK), which may or may not be fully transferred into practice.
- ❖ Written CoRes do not reveal teachers' genuine PCK unless exposed in a class, as PCK is both observable and internal.
- ❖ Teachers must communicate the PCK for a researcher, for instance, to draw meaningful inferences about the PCK because it is ingrained in their minds. Consequently, observing teachers in the classroom provides only a restricted perspective of their PCK.

1.8. RESEARCH DESIGN AND METHODOLOGY

This study took a qualitative research approach, driven by an interpretivist framework. A single-case study research design was deemed adequate for addressing the research concerns. Interviews and classroom observations were conducted to explore how electrical technology teachers' pPCK and ePCK of three-phase induction motors manifest in the classroom. The research design and methodology are discussed in Chapter 3.

1.8.1. Data collection and documentation

This study's findings were gathered through interviews and classroom observations. An interview is an organised discussion in which the researcher asks questions and the teacher provides answers (Knox & Burkard, 2009). Interviews aid in understanding people's experiences and the interpretations they make of them (Ary et al., 2018). Interviews were conducted to explore the teachers' pPCK. The interviews occurred in the teachers' offices, workshops, or convenient places after school. Classroom observations were performed to investigate the teacher's ePCK. The observations occurred during school hours in the teachers' classrooms or workshops. Using at least one Grade 12 lesson for each teacher sampled on three-phase induction motors, at least one lesson per teacher was observed to investigate the teachers' ePCK.

I used Coetzee's (Coetzee, 2018) adapted content representation (CoRe) tool to collect the data. Loughran et al. (2004) created this data collection tool for documenting and demonstrating teachers' PCK. Refer to Chapter 2, Section 2.4 and Section 2.5, for an in-depth explanation of the CoRe tool.

1.8.2. Data analysis and interpretation

One of the most important aspects of qualitative research is qualitative data analysis, which assists researchers in making sense of their qualitative data (Leech & Onwuegbuzie, 2007). Instead of emphasising the statistical significance and correlations between variables, the qualitative analysis concentrates on the importance of experiences and acts (Ngulube, 2015). After the organisation and preliminary analysis of the data, the data were classified according to the PCK components shown in Chapter 2 (see Table 2.1). The prompts in Table 2.1 were used during the interviews. Participants' answers were organised according to the PCK components in the left column. For the observations, the prompts in the right column of Table 2.1 aided in recognising and reporting the relevant PCK component. By presenting the data in terms of PCK components (Table 2.1), I could characterise and compare the teachers' pPCK and ePCK. Section 3.7 explains how the data were processed and interpreted.

1.8.3. Quality assurance

The rigour of the research was strengthened by addressing the study's credibility, transferability, dependability, and confirmability, as advised by (Ghafouri & Ofoghi, 2016). These standards of rigour are discussed in Chapter 3, Section 3.8. In addition, the study was conducted in a stress-free environment to ensure that participants' apprehension did not influence their responses. Interviews and observations were conducted in the teachers' environment to improve the comfort and quality of the interviews and observations.

1.8.4. Ethical Considerations

To guarantee that the research was done ethically, the University of Pretoria's Ethics Committee provided clearance. Before the study began, teachers, parents, and students received consent and assent papers to ensure that they were familiar with the study and understood its consequences. According to the forms, participation is entirely optional, and withdrawal is permitted at any moment. Their names were kept private. The study method followed stringent guidelines established by the ethics committee. The study began only after obtaining approval and consent from the Ethics Committee, the Department of Basic Education, and the schools involved.

1.9. CONCEPTUAL FRAMEWORK

For the conceptual framework, I used the Refined Consensus Model (RCM) (see Figure 2.1). The RCM shows three separate PCK realms that guided my study. These realms are collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK). This study focused on the pPCK, ePCK, and PCK components adapted by Coetzee (2018, p. 187) to document and demonstrate electrical technology teachers' PCK. The concepts in this section are thoroughly explained in Chapter 2 of Section 2.7.

1.10. CONCEPT CLARIFICATION

1.10.1. Curriculum Assessment Policy Statement document (CAPS)

The National Curriculum and Assessment Policy Statement has superseded the Subject and Learning Area Statements, Learning Programme Guidelines, and Subject Assessment Guidelines for all topics mentioned in the National Curriculum Statement for Grades R-12 (DoBE, 2011). This is a single, comprehensive, and simple policy document.

1.10.2.Practical Assessment Tasks (PATs)

According to the DoBE (2011), a PAT is a formal evaluation in which learners are required to use the knowledge and skills they have learned in class to produce articles or address actual electrical issues. In electrical technology, learners must complete a set of practical tasks in a workshop. For every learner enrolled in electrical technology, a practical assessment task is a required part of the final promotion grade and must account for 25% of the final examination mark (DoBE, 2011).

1.11. OUTLINE AND ORGANISATION OF THIS STUDY

This study is divided into five chapters, which are structured as follows.

Chapter 1 Orientation of the Study

In this chapter, I provide an overview of the study's background and the issue statement, rationale, goals, objectives, and research questions that guided it. After formulating the research goals and working assumptions, I addressed the study's relevance and the key terms used. I close this chapter by offering the conceptual framework of my study, where I utilised the RCM and the PCK components by Carlson et al. (2019) and Loughran et al. (2004) respectively.

Chapter 2 Literature Review

In Chapter 2, I provide an outline of knowledge and PCK as the study's context. I also look at the PCK components as a method for explaining electrical technology teachers' curricular relevance, knowledge and abilities linked to conceptual teaching strategies, and students' grasp of technology. These PCK components enabled me to investigate Coetzee's (2018) customised CoRe, which resulted in a PCK capture and documentation tool. Next, I talked about the conceptual framework for this study, which incorporated the RCM and PCK components.

Chapter 3 Design and Methodology

In Chapter 3, I discuss the research techniques and strategies that led my techniques and describe my paradigmatic and methodological choices, as well as the study design, case and participant selection, data collecting and documentation tactics, and data analysis and interpretation methods. lastly, I address my position as a researcher, as well as the quality metrics and ethical issues that guided this work.

Chapter 4 Results and Discussions

In this chapter, I provide the findings from this investigation. My chapter explains how I gathered and evaluated the data to answer the main question and the three sub-research questions of this study. In terms of my interpretation of the pPCK discussed by teachers during interviews and their ePCK demonstrated during a classroom observation, I used a rubric to measure the teachers' pPCK and ePCK. then, I compared the teachers' pPCK and ePCK to conclude my discussion.

Chapter 5 Summary, Limitations, and Recommendations

The last chapter of this study summarises the important results and conclusions I could make in response to the research questions. In expressing the study's results, I highlight the possible theoretical and practical contributions. I concentrated on improving transferability and generalisability by expanding the sample size of the new research and the inclusion of plenary materials. I finish this chapter by addressing some of my study's shortcomings and making recommendations for future research in electrical technology education settings.

1.12. SUMMARY

In Chapter 1, the importance of PCK, and the three realms of PCK that guided the study were discussed. It has been argued that teachers require sufficient PCK to teach successfully. Changes to the CAPS document for electrical technology in South Africa may exacerbate learners' understanding of electricity concepts which may indicate a need for teacher development. Curriculum changes in the three-phase induction motors' topic led to teacher developmental workshops that helped identify the purpose, rationale, and significance of the study. Interpretivism and qualitative research were utilised to study electrical technology teachers' pPCK and the way they enact it in the classroom. The CF was used to guide the formulation of the research questions and align and inform the data collection, analysis, and interpretation. The adapted by Coetzee (2018) was used to document and demonstrate electrical technology teachers' PCK.

2. CHAPTER TWO: LITERATURE REVIEW

2.1. Overview of the chapter

In Chapter 2, I present an overview of the literature relevant to this study. The literature review commences with a discussion of different knowledge types and their importance in shaping teachers' PCK. The focus then shifts to a discussion of Pedagogical Content Knowledge (PCK) and its three realms: collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK). The PCK components are then discussed, along with the adapted CoRe used to collect and measure PCK. These tools make it possible to describe the assessment of PCK. The conceptual framework that guided the study is then discussed.

2.2. Knowledge

Knowledge, as examined through the lens of justified true belief (JTB), is a philosophical idea that aims to comprehend the circumstances under which a belief may be deemed knowledge. The justified true belief (JTB) hypothesis, first expressed by Plato, translated by Jowett (2023), and later modified by philosophers such as Gettier (1963), states that knowledge involves three basic components: truth, belief, and justification. The first factor, truth, suggests that the belief must properly reflect objective reality. Second, believing implies that the individual holds the belief in question (Gettier, 1963). Finally, justification refers to the availability of acceptable grounds or facts to justify the view, hence removing the possibility of simple guesswork (Gettier, 1963). According to the JTB model, as stated by Gettier (1963), knowledge is more than simply a true belief; it is also justified, which gives the individual's cognitive attitude a solid foundation and credibility.

Anderson and Krathwohl (2001) revised Bloom's Taxonomy, a classification of educational objectives that incorporates a hierarchy of cognitive processes. Anderson and Krathwohl (2001) expanded the basic framework to incorporate a dimension connected to knowledge, which distinguishes between different forms of knowledge. Anderson and Krathwohl established four forms of knowledge: factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge.

According to Anderson and Krathwohl (2001), factual knowledge refers to the recall of specific information such as facts, dates, and terminology. In the Pedagogical Content Knowledge (PCK) framework, teachers must have a factual understanding of the material they teach. For example, a history teacher must be well-versed in historical facts to communicate with learners successfully.

Conceptual knowledge refers to the comprehension of concepts and principles (Krathwohl, 2002). In PCK, conceptual knowledge comprises understanding the fundamental principles that govern a subject (Shulman, 1986). Understanding the fundamental principles of algebra and geometry allows mathematics teachers to convey their ideas to learners in a relevant manner.

According to Anderson and Krathwohl (2001), procedural knowledge entails an understanding of how to complete tasks and procedures. In PCK, procedural knowledge is essential for teachers to effectively communicate the procedures and processes involved in problem resolution. For example, a science teacher must be procedurally knowledgeable to direct learners through laboratory experiments.

Metacognitive knowledge refers to the ability to comprehend and manage one's cognitive processes (Pintrich, 2002). In PCK, metacognitive knowledge can help teachers reflect on their teaching techniques and make changes to improve their learning outcomes. This might include exploring alternative ways or correcting student misunderstandings. The subset knowledge type useful in correcting student misunderstanding is strategic knowledge. Strategic knowledge refers to knowing when and how to apply various cognitive processes to improve learning and problem-solving. In PCK, strategic knowledge is required for teachers to adjust their teaching tactics according to the requirements of their learners. For example, an electrical technology teacher may use a variety of teaching methods, such as demonstrations and direct instruction, to accommodate different learning styles in the classroom.

2.3. Pedagogical Content Knowledge (PCK)

PCK, first developed by Lee Shulman in 1986, refers to teachers' specialised knowledge that combines subject and pedagogical practices to successfully assist student learning. A teacher's professional knowledge base includes components such as subject knowledge, pedagogical knowledge, assessment knowledge, curricular knowledge, and knowledge of learners (Carlson et al., 2019; Garritz, 2015). Each of these components feeds into developing teachers' pedagogical content knowledge (PCK) (Garritz, 2015). PCK is essential to teachers' professional growth; it is described as the knowledge that is uniquely designed for preparing and teaching a specific subject, and that knowledge is exclusive to that subject (Shulman, 1986). PCK is divided into three realms, namely collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK).

2.3.1. Collective PCK (cPCK):

A teacher's cPCK comprises the contributions of numerous teachers, including the teacher's work, and those derived from shared professional knowledge and a variety of teaching experiences within a certain subject area, as interpreted and recorded by other individuals (Hume et al., 2019). This realm of PCK stresses the collaborative aspect of teaching, recognising that by sharing their unique skills and experiences with others, teachers may build a more thorough understanding of their subjects (Timperley et al., 2007). Collaboration-based professional development programmes have been found to increase the acquisition and sharing of cPCK. According to research, teacher partnerships that integrate enquiry into practice can improve both teachers' knowledge and learners' performance (Vescio et al., 2008).

One key advantage of cPCK is its capacity to holistically address learners' various needs. Teachers can better adapt to unique learning styles and foster deeper comprehension by combining the knowledge and strategies of several teachers (Muijs & Reynolds, 2017). This inclusive approach offers teachers the confidence to explore previously difficult topics and creates a welcoming environment in which learners are encouraged to participate in active learning.

2.3.2. Personal PCK (pPCK):

Since cPCK is the collective professional knowledge of different individuals, the teacher's pPCK is the collective and vibrant pedagogical content knowledge of an individual teacher, which supports the teacher's interactions during teaching and learning in classroom situations (Shulman, 1986). PCK incorporates subject knowledge, curriculum, learner understanding and misunderstandings, and instructional methodologies (Garritz, 2010; Shulman, 1986). Personal PCK development thus requires knowledge of one's strengths and shortcomings, as well as a strong understanding of learners' educational requirements. PPCK is developed through training and experience and is simply an individual's knowledge about specific content for teaching and learning (Rollnick, 2017).

Teachers with good pPCK are better at adapting their lessons to meet learners' specific requirements (Azam, 2020). According to research, teachers with deep PCK are better able to engage learners in learning activities, successfully resolve misunderstandings, and establish a learning atmosphere that stimulates curiosity (Nilsson, 2008). Ball et al. (2008) point out that successful teachers have flexible knowledge that extends beyond their subject knowledge; this flexibility is gained through the development of pPCK.

Professional development opportunities and critical reflection can help teachers improve their pPCK (Kleickmann et al., 2013). It has also been suggested that teachers engage in communities of practice where they may exchange ideas, share experiences, and learn from other teachers (Loughran, 2010). These collaborative contacts help improve pPCK by providing a variety of perspectives on instruction, curriculum design, and assessment procedures.

Teachers may supplement their pPCK by remaining updated on the findings of studies and applying evidence-based strategies. Teachers can experiment with different educational strategies and measure their success by conducting action research in their classrooms (Mena et al., 2016). Furthermore, reading about teaching and learning in their subject areas might help teachers improve their knowledge of student misunderstandings (Hsu et al., 2017).

2.3.3. Enacted PCK (ePCK):

Enacted PCK is the knowledge a teacher uses for the development of the material used and the application of the resources to the teaching and learning of a specific classroom using the pedagogical content and knowledge of the learners (Carlson et al., 2019; Vázquez-Bernal et al., 2021). Carlson et al. (2019) further expand on ePCK as the teacher's choices related to a particular content to learners in a specific context; the teacher's perspective will inform his/ her choice in the content of what is important for the specific learners. Park and Oliver (2008) view ePCK as the capacity of teachers to turn their subject knowledge into learning experiences that are easily understood and relevant to their learners.

Enacted PCK has an important function in fostering deeper learning and understanding among learners. Teachers with exceptional ePCK may help students understand complicated topics by presenting curricular materials using successful teaching tactics, such as analogies, drawings, and real-life examples (Lee & Luft, 2008). These teachers have a better awareness of student misunderstandings and can successfully address them through their teaching approaches. As such, teachers' development of ePCK is essential for improving learners' performance. According to previous research, learners taught by teachers with sufficient PCK outperform those taught by teachers with insufficient PCK in assessments (Ball et al., 2008; Gess-Newsome et al., 2019). Learners who are guided by teachers with exceptional PCK not only have higher test results but also better enthusiasm for learning and a stronger willingness to investigate difficult subjects (Gess-Newsome & Lederman, 1999). The next section focuses on investigating PCK components to better understand how to improve teachers' PCK.

2.4. PCK Components

Loughran et al. (2004) developed an instrument for measuring teachers' PCK. The instrument called the Content Representation (CoRe), comprised eight PCK components: content topic definition, significant teaching issues, knowledge of learners' understanding, goals of teaching the topic, domain-specific strategies, methods of determining students' understanding, topic-specific knowledge for teaching, and sequences of topic-based instructions (Loughran, 2014). These components provide a complete depiction of a teacher's PCK by describing their topic competence and pedagogical practices while consistently highlighting the subject context.

Collaboration with experienced chemistry teachers, who shared their classroom practices through workshops and group discussions, was required to create the CoRe as a tool (Loughran, 2004). The goal of this collaborative method was to derive knowledge from teachers' experiences and link them with theoretical ideas on PCK. CoRe has emerged as a reliable instrument for measuring and improving PCK in modern educational settings after several iterative research cycles, including data gathering and analysis approaches such as classroom observations and interviews (Nilsson & Loughran, 2012).

The CoRe tool provides a comprehensive way to measure teachers' PCK, and a realistic foundation for improving their teaching strategies (Loughran et al., 2004). CoRe assists both new and experienced teachers in building their PCK through the integration of research-based methodologies with real-world skills and experience (Loughran, 2014). CoRe is likely to play a vital role in the continuous development of successful teaching practices as PCK remains a focal point in educational research.

Coetzee (2018, p. 187) adapted the CoRe tool to measure science teachers' PCK. The adapted CoRe tool was used to collect and analyse PCK data from teachers during interviews and observations. The data collection tool in Table 2.1 was created by Loughran et al. (2004) and adapted for documenting, measuring, and demonstrating teachers' PCK. This tool made it possible to identify the participating teachers' PCK components of three-phase induction motors during the interviews (pPCK) and while teaching the topic (ePCK). The table is divided into two columns, namely PCK components and CoRe-prompts.

2.5. Adapted CoRe-Prompts

The use of Table 2.1 begins with the selection of big ideas for three-phase induction motors. Each big idea must be analysed using the CoRe-prompts indicated on the right side of Table 2.1. The teacher's responses regarding the big ideas under each PCK component give a picture of the PCK the teacher possesses, and the prompts will allow me to recognise and report on the relevant PCK component during observations.

Table 2.1: *The CoRe-Prompts and PCK components, adapted by Coetzee (2018)*

PCK components	CoRe-Prompts
Knowledge and skills related to curricular saliency	• Selection of key ideas. • What do you intend the learners to know about this idea? • Why is it important for learners to know this? • What concepts need to be taught before teaching this idea? • What else do you know about this idea that learners may learn later?
Knowledge and skills related to conceptual teaching strategies	• What representations would you use in your teaching strategy? • What questions would you consider important to ask in your teaching strategy? • Describe the strategy you will use to establish conceptual development of the key idea.
Knowledge and skills related to student understanding of technology	• What do learners find difficult to understand and why? • What are typical learners' misconceptions about pre-concepts that affect teaching this key idea? • What ways would you use to assess learners' understanding?

The adapted CoRe-prompts are useful tools for documenting, measuring, and reporting teachers' PCK. Coetzee (2018) developed a rubric Coetzee (2018) by combining CoRe-prompts and the PCK grand rubric (Mavhunga & Rollnick, 2011). The tool used in this study (see Appendix C) was developed based on Table 2.1. Appendix C was created with the assistance of electrical technology subject specialists in Gauteng. Appendix F shows the subject specialist's biographical information.

2.6. The assessment of PCK

PCK is a conceptual concept that differentiates teachers from other topic specialists. However, teachers seldom transmit this information in their everyday discourse since there is no purpose or expectation for them to explain their pedagogical reasons for teaching the way they do, and they need to be made aware of the knowledge they contain (Loughran et al., 2004). The value of capturing and measuring PCK cannot be accentuated sufficiently because it is central to good teaching (Loughran, 2012). A thorough understanding of PCK allows teachers to make informed decisions regarding instructional approaches, resources, and assessments in each subject area, resulting in improved learner outcomes (Nilsson, 2008).

Over the last decade, there has been a major increase in research on approaches to documenting and assessing PCK (Park & Oliver, 2008). Loughran's (2010) CoRe framework, for example, has proven useful in eliciting PCK by offering a systematic mechanism for teachers to reflect on and portray their subject-specific knowledge. Rollnick and Mavhunga's (2016) research demonstrates how chemistry teachers' PCK may be captured and assessed using the adapted CoRe to develop big ideas to aid the comprehension of scientific principles and related teaching strategies. When employed together or separately, these strategies enable teachers and researchers to gain a deeper understanding of the complexity of PCK. Table 2.2 represents the adapted CoRe for Task-Specific Pedagogical Content Knowledge TSPCK (Rollnick & Mavhunga, 2016).

***Table 2.2**: Skeleton adapted CoRe by Rollnick and Mavhunga (2016)*

To be developed for each Big Idea
A. Curricular Saliency
A1. What do you intend students to learn about this idea? (In original CoRe) A2. Why is it important for students to know this? (In original CoRe) A3. What concepts need to be taught before this big idea? (Only in adapted CoRe) What else do you know about this idea that you don't intend students to know yet? (In original CoRe)
B. What makes a topic easy or difficult to understand
B1. What do you consider easy or difficult about teaching this idea? (Original CoRe: Difficulties/limitations connected with teaching this idea)
C. Learner Prior Knowledge
C1. What are typical students' misconceptions when teaching this idea? (Original CoRe: Knowledge about students' thinking that influences your teaching of this idea)
D. Conceptual Teaching Strategies
D1. What effective teaching strategies would you use to teach this big idea? D2: What questions would you consider important to ask in your teaching strategy? (Original CoRe: teaching procedures)
E. Representations
E1 What representations would you use in your teaching strategy? (Only in adapted CoRe)
Additional Questions not linked to a specific component
What ways would you use to assess students' understanding (original CoRe: Specific ways of ascertaining understanding)
What aspects of teaching and planning for this big idea would you like to reflect on? (Only in adapted CoRe)

TSPCK refers to the specialised knowledge and understanding that teachers must have to successfully teach their subject, taking into consideration the unique situation and the learners being taught. TSPCK combines topic knowledge with a suitable pedagogy to successfully assist student learning (Mavhunga & Rollnick, 2013). The TSPCK skeleton developed by Mavhunga and Rollnick (2013) was used to capture and measure PCK by developing big ideas for the topic and a rubric to measure it (Appendix C). The "big ideas", which are the column heads in the original CoRe instrument, are essential ideas or core concepts that support the comprehension of a certain science issue, and the remainder of the prompts are filled regarding these large ideas.

According to Mavhunga and Rollnick (2013), there are five major components within the TSPCK rubric:

1. Learner prior knowledge: A teacher's capacity to discern students' misunderstandings, prior knowledge, and learning challenges in the subject is referred to as the knowledge of student understanding. Teachers must be able to successfully handle these difficulties by using their pedagogical talent to obtain the best learning results.

2. Curricular saliency: Teachers must comprehend the curriculum and its organisation. This comprises subject-specific objectives and curricular material sequencing, which allows for successful teaching strategies that are adapted to learners' requirements (Loughran et al., 2012).

3. Representations: This component focuses on a teacher's capacity to explain complicated or abstract topics in easy and accessible ways, using analogies, examples, or metaphors (Loughran et al., 2006). Teachers can assist students in creating cognitive links between new materials and prior knowledge by doing so.

4. Conceptual teaching strategies: Teachers should be able to apply a range of instructional strategies that are specific to the subject being taught. Examples include questioning approaches, enquiry-based or experiential methods, problem-solving strategies, and others that best suit the nature of the topic (Mavhunga & Rollnick, 2013).

5. Assessment Knowledge: Effective teachers must be skilled in developing rigorous exams that are aligned with curriculum objectives and provide reliable measurements of a learner's comprehension. Teachers should be able to use such evaluations to identify areas for improvement, track learners' progress, and change instruction accordingly (Loughran et al., 2006).

The rubric in Appendix C was used for both interviews and classroom observations. During the interviews, each teacher's replies to the questions were written on a separate sheet, and the rubric was used to quantify the responses. Each response was rated on a scale of 1 to 4, with 1 indicating insufficient understanding and 4 indicating exceptional knowledge. The recording of the responses ensured that each teacher’s PCK was correctly quantified, making the analysis easy.

2.7. Conceptual framework

Since this study focused on the pPCK and ePCK of electrical technology teachers, using the adapted Refined Consensus Model (RCM) as the conceptual framework (Figure 2.1) seemed appropriate as it allows the analysis of relationships between each layer in a logical manner. The RCM indicates that three separate PCK realms, namely collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK), reflect the specialised professional knowledge held by numerous individuals, a fundamental component of this model. The RCM was adapted by adding the PCK components identified by (Loughran et al., 2004). This conceptual framework was chosen because it makes it easy to analyse the relationship between the PCK realms and the CoRe-prompt tool.

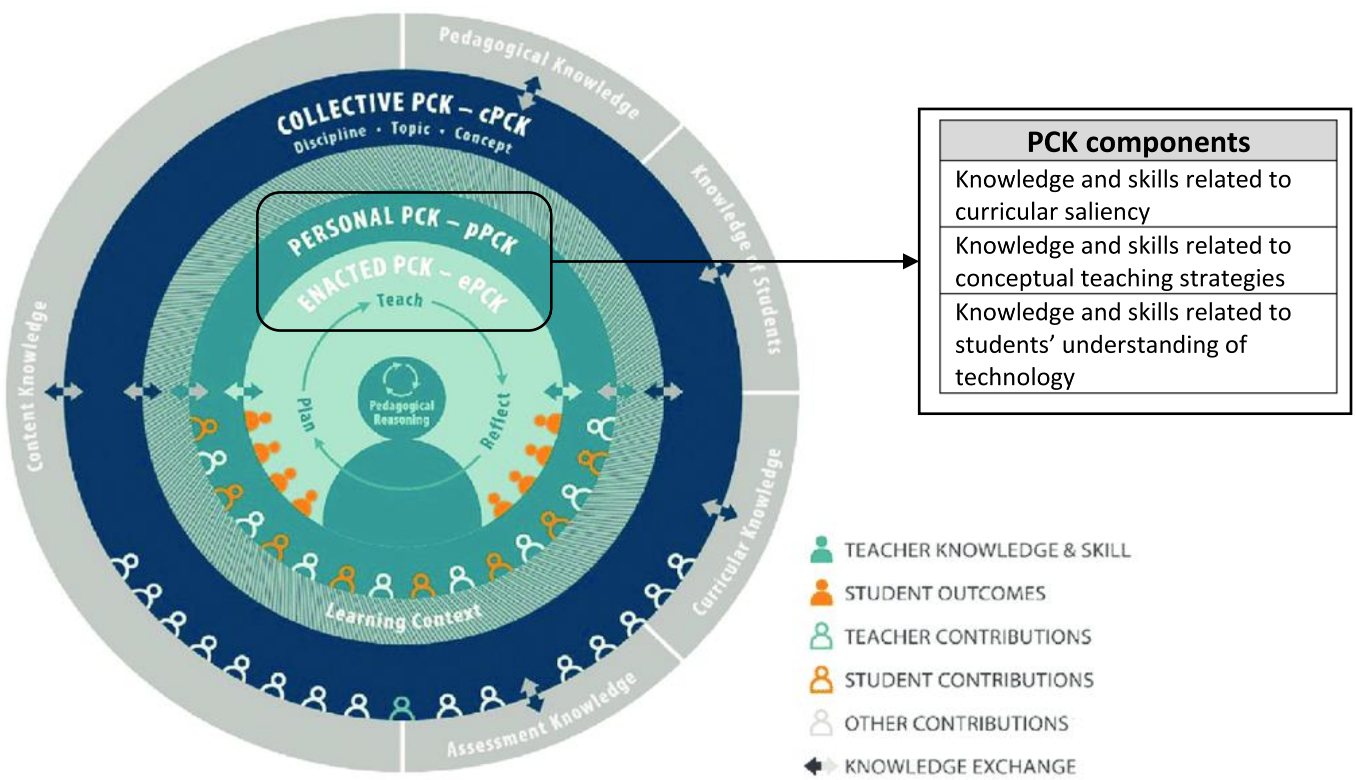


Figure 2.1: *Adapted Refined Consensus Model of PCK and the PCK components (Carlson et al., 2019; Loughran et al., 2004)*

Figure 2.1 shows the two-way knowledge exchange ( ) between the concentric circles of the RCM during a teacher's career and PCK components. This study focused on the knowledge and exchange between pPCK and ePCK. Knowledge exchange refers to teachers’ and learners’ different contributions (Carlson et al., 2019). From the definition of pPCK, we can deduce that the knowledge exchange between learners and teachers on a particular topic affects how teachers approach that topic.

Furthermore, a teacher's amplifiers and filters, which inform the specific professional knowledge used in the practice of teaching (i.e. enacted PCK), serve as moderators for knowledge exchanges when teachers make instructional decisions related to teaching content to specific students in a specific context (Carlson et al., 2019). PCK amplifiers include professional development seminars, collaborations with colleagues using Professional Learning Communities (PLCs), mentoring relationships, classroom observations and reflective practices. This can help a teacher amplify the ePCK for better content delivery to learners. PCK filters can be the teacher’s teaching philosophy: A teacher's convictions about education, students, and teaching practices might influence whether new ideas or methods provided through professional development opportunities are adopted or rejected. The amount of specialised professional expertise used in the classroom may be influenced by factors such as school leadership, curricular requirements, and accessible resources. The specific characteristics of each classroom, such as student demographics, learning requirements, and subjects, may influence the implementation of certain components of professional knowledge. Personal history and experience, as well as balanced obligations such as lesson planning, grading, meetings, extracurricular activities, and other duties, may limit teachers' ability to fully utilise or experiment with newly acquired professional knowledge.

The teacher's choices related to a particular content to learners in a specific context; the teacher's perspective that will inform their choice in the content of what is important for the particular learners is known as ePCK, as the teacher considers the learners, context, and what is important for the learners to know (Vázquez-Bernal et al., 2021). Individual teachers can then develop their pPCK by conversing and sharing information with other learners and teachers. The information exchange may also have an impact on their ePCK in the future.

The PCK components in Figure 2.1 form the main headings of the CoRe tool. The CoRe tool developed by Loughran et al. (2004) sought PCK using various methods, including content-specific teaching techniques like role-plays, laboratory work, demonstrations, etc.; discussions with teachers about their instruction; classroom observation; and other "traditional" methods of observing skilled science teachers' "knowledge through practice." This resulted from requesting PCK from knowledgeable scientific teachers who could not describe their PCK while having a well-developed PCK. Loughran et al. (2004) developed an activity to get teachers to think about and share their knowledge about teaching science content, leading to the development of Content Representation, or CoRe.

2.8. SUMMARY

In summary, PCK is an important concept in education, as it helps teachers combine their comprehension of topic knowledge with effective teaching techniques. PCK combines declarative, procedural, and tacit knowledge to help teachers create and deliver effective teaching only if they have a sound understanding of PCK. EPCK includes the ability to make learning interesting and accessible, drawing on teachers' individual experiences, and modifying the curriculum to meet the demands of different learners. The CoRe tool contains PCK components that are used to collect and analyse PCK data from teachers during interviews or observations. The CoRe-prompt tool was developed to help teachers think about and share their knowledge of teaching science content. Since electrical technology is a section of science, the CoRe-prompt tool became useful in gathering information. The adapted CoRe by Coetzee (2018) provided a means to measure the PCK by using a rubric. The conceptual framework discussed provided the theoretical foundation for understanding and analysing various components of a research study.

3. CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1. OVERVIEW OF THE CHAPTER

This chapter describes the research plan and methods for this study. First, the interpretivist paradigm that guides this work is described and explained. The qualitative research approach, which utilised a single case study design, is then discussed. The ideas and arguments for non-probability sampling are then examined, as well as data collection approaches such as interviews and classroom observations. The method of theme analysis utilised to examine the data acquired is then discussed. The study's rigour and ethics are then described.

3.2. PARADIGMATIC APPROACH: INTERPRETIVISM

Filstead (1979, p. 34) defines a paradigm as a "set of interrelated assumptions about the social world that provides a philosophical and conceptual framework for the organised study of that world." The selected paradigm guides the researcher's philosophical convictions about the research, as well as the instruments, processes, participants, and methodology used in the study (Denzin & Lincoln, 2008). In this study, I used an interpretivist paradigm. According to interpretivism, it is essential to comprehend the context of any research to correctly interpret the information obtained (Willis et al., 2007). The interpretive paradigm presents the world as socially produced, intricate, and dynamic (Thanh & Thanh, 2015). Using the interpretivism paradigm and qualitative research, one can investigate and comprehend the significance that expert teachers assign to the PCK realms to be investigated (Creswell & Creswell, 2017). Therefore, using interpretivism, I will create an understanding of teachers' pPCK and investigate how ePCK manifests in their classrooms based on the experiences and opinions of expert teachers. The implications of the selected paradigm will now be investigated in terms of the philosophical anchors of ontology, epistemology, and methodology (Ponterotto, 2005).

Ontology is the study of the nature and forms of reality, and interpretivists hold that there are numerous constructed realities (Ponterotto, 2005). The interpretivist position understands that reality is subjective and is affected by the context of the situation, including the person's experience and views, social environment, and contact with the researcher (Ponterotto, 2005; Schwandt, 1994). Interpretive researchers understand that social processes and cultural circumstances impact how people perceive their environment (Denzin & Lincoln, 2011). The ontological implication of this study was that multiple interviews and classroom observations were conducted to capture a broad spectrum of realities.

Epistemology refers to how knowledge is generated or acquired (Ponterotto, 2005). According to interpretivism, knowledge is created using subjective experiences and interactions between researchers and their subjects (Crotty, 1998; Ponterotto, 2005; Schwandt, 1994). The interaction between the teachers and the researcher is a crucial component of the data-gathering phase and cannot be disregarded because interpretivists believe that reality is socially constituted. The epistemological implications of this on my research were that during the interviews and observations, the relationships I had with the teacher and learners were considered professional and focused on the research questions during the enquiry. This ensured that the teacher's response to questions or how learners behaved during observations would yield the desired results.

The methodology in research is when the researcher must interact with the teachers and students as much as possible in the study's naturalistic design, as required by the processes and methods of a search based on the interpretivist paradigm (Lincoln & Guba, 1985; Ponterotto, 2005). A more naturalistic investigation, such as interviews and observations, is required for a qualitative research method which is supported by the interpretivism paradigm (Lincoln & Guba, 1985). These methods of enquiry allow researchers to fully immerse themselves in the subjects' social environments to develop a thorough understanding of their experiences (Atkinson et al., 2003). In conclusion, the methodology explains the rationale and flow of the organised procedures used to carry out a research project (Kivunja & Kuyini, 2017). For my study, I ensured that I spent a lot of time in the classroom during my observations to obtain a more naturalistic response from the learners.

3.3. RESEARCH APPROACH: QUALITATIVE

This study made use of qualitative research methods. The qualitative research approach allows the researcher to focus largely on each participant's experiences and understanding of the examined topic (Baxter & Jack, 2008). In addition, this method examines and comprehends the significance that different people or groups assign to social or human problems (Creswell & Creswell, 2017). Creswell and Creswell (2017) Add that the research process includes generating questions and procedures, data collecting that typically takes place in the participant's surroundings, inductive data processing that builds from particular to broad themes, and the researcher's appraisal of the relevance of the results. Hence, the qualitative approach made it easy to expose the PCK of electrical technology teachers, as this method focuses more on the natural environment and people’s experiences than on producing numerical statistics. (Maree, 2019). Qualitative research provides participants with the opportunity to express their experiences by preparing and applying strategies that assist them in enacting their PCK.

However, qualitative research has certain limitations. The results may not be generalisable or relevant outside the group investigated, because they focus on individual experiences and viewpoints (Maxwell, 2012a). Additionally, if researchers do not follow best practices, such as reflexivity and triangulation, subjectivity during data analysis may lead to biased interpretations (Jenner et al., 2004). One key goal of adopting qualitative research methods is to investigate topics that are unknown or under-researched (Maxwell, 2012b). Since qualitative researchers value flexibility over control, they can change their approaches during a study and uncover new insights as they dive into the viewpoints of participants. Researchers may identify prevalent topics or themes using methods such as interviews or focus groups that are not visible through numerical data (Creswell & Poth, 2016). Furthermore, qualitative research is useful for exploring phenomena that cannot be studied using quantitative methods alone. Qualitative research enables researchers to investigate the multidimensional characteristics of social relationships (Liamputtong, 2019). It enables researchers, for example, to investigate how diverse cultural origins impact behaviour and values. Furthermore, qualitative approaches can enable a thorough examination of delicate themes that may not be adequately or morally addressed statistically. Thus, by capturing individuals' subjective experiences, qualitative research provides major benefits for understanding complicated social problems.

3.4. RESEARCH DESIGN: SINGLE CASE STUDY

My study employed a single case study research design driven by an interpretivist paradigm. A case study is a thorough and in-depth examination of a single case in a practical situation (Yin, 2009). Gerring (2004, p. 342), discusses a case study as "an intensive study of a single unit... a spatially bounded phenomenon, e.g. a nation-state, revolution, political party, election, or person - observed at a single point in time or over some delimited time." The case in this study comprised the PCK observed from Grade 12 electrical technology teachers. A case study assists in the deconstruction and subsequent reconstruction of different phenomena and allows the researcher to analyse individuals or organisations, basic to sophisticated interventions, relationships, communities, or programmes (Yin, 2009). According to Yin (2009), since comparisons will be made, examples must be carefully selected so that the researcher can predict consistent findings across instances or inconsistent outcomes depending on a hypothesis.

The advantages of a qualitative single case study approach include the capacity to analyse a phenomenon in its context utilising a variety of sources (Baxter & Jack, 2008). This ensures that the topic is not explored through a single lens, but via a multiplicity of lenses, allowing for the discovery and comprehension of numerous aspects of the phenomena. Thomas (2011) believes that case studies help generate new thoughts and reveal the creation of new theories, especially for new theory generation or extension. As new literature is added to the body of knowledge, this claim supports my study on the PCK of electrical technology teachers and may serve as a guide for future researchers in PCK or electrical technology.

According to Hyett et al. (2014), one disadvantage of case studies is that they lack a statistical purpose and do not strive to create outcomes that can apply to all populations. This is becoming increasingly frequent among qualitative researchers. Consequently, its comparison with other methodologies does not help with this qualitative technique, failing to acknowledge the underlying worth of qualitative case studies. Furthermore, a case study report might be difficult for any researcher to write because of the complexity of this approach (Baxter & Jack, 2008). Despite the difficulty of summarising the data, the researcher must describe a complicated phenomenon in a way that the reader may readily grasp. Thus, conducting case study research might take a long time since it entails learning many details about a specific person or group. Consequently, it can be challenging for researchers to complete several case studies quickly.

Overall, a single case study analysis can offer complex, rich empirical evidence and a comprehensive description of certain occurrences by applying qualitative research methodologies. This may be especially applicable for phenomena that are less susceptible to more thorough testing and measurements, as well as for those for which the reasons for comprehending and/or explaining them are infinitely subjective. Being aware of the limitations of this research method, such as limited generalisability and subjectivity. This method helped me to qualitatively understand the PCK of electrical technology teachers in three-phase motors among the teachers sampled in Gauteng.

3.5. SAMPLING: non-probability

The non-probability sampling approach (quota sampling) was utilised for the single case study technique because case studies often focus on small samples and are designed to examine real-world events rather than conclude the overall population based on data (Yin, 2009). Convenience sampling helped me select participants in and around Gauteng because it was easier to reach them, they were readily available, and not too costly, as pointed out by Taherdoost (2016). In my sampling criteria, I focused on teaching experience, geographic location and willingness to participate. Under teaching experience, I chose teachers with different degrees of knowledge to capture a variety of viewpoints and teaching methods. This included both inexperienced teachers and those with more years of experience teaching electrical technology in Grade 12. I also used teachers with a good record of success in Grade 12. As schools are believed to deploy their finest teachers to teach the exit Grade of FET to tertiary-level students, Grade 12 teachers were sampled. These teachers with a good track record were selected around Gauteng to account for any differences in curriculum implementation, finances, and contextual variables. This meant that the findings were not limited to a certain school or location, but could be applied broadly across the province.

Six electrical technology teachers were chosen for interviews and of the six, five were chosen for observations. The sample size for the interviews and observations was chosen based on the saturation principle. Data saturation occurs when there is sufficient information to replicate the study, the ability to obtain extra new information is attained, and further coding is no longer practicable (Fusch & Ness, 2015). Saturation was determined by using an adapted rubric that was initially used for scoring CoRes on electric circuits (see Section 3.6.1.1).

3.6. DATA COLLECTION TECHNIQUES AND DOCUMENTATION

The researcher conducted semi-structured interviews and classroom observations (Appendices A and B). Appendix C represents a data organising rubric to measure teachers' PCK based on the results of the interviews and lesson observations. An interview is a scheduled discussion where the researcher asks questions and the teacher answers (Knox & Burkard, 2009). Interviews help us comprehend the experiences of individuals and the significance of those experiences (Ary et al., 2018). Interviews were conducted in teachers' offices, workshops, or convenient places after school, and classroom observations were conducted during school hours. Using at least one Grade 12 lesson for each teacher sampled on three-phase induction motors, the teachers were observed to investigate their ePCK. Observations are useful data-gathering methods in research, providing personal insights into behaviours, relationships, and occurrences in naturalistic situations. Researchers can get rich, contextually relevant data by routinely monitoring people in their natural settings, which may be difficult to obtain using other approaches. Researchers can use observations to investigate emerging themes, confirm or question current ideas, and produce new hypotheses, all of which contribute to the progress of knowledge in diverse domains (Bogdan & Biklen, 1997; Patton, 2014).

3.6.1. Data collection instruments

The conceptual framework (Figure 2.1) was used to create the data-gathering instruments. Table 2.1 was used to generate the interview questions in Appendix A. By capturing experienced teachers' PCK through interviews and lesson observations, the CoRe-prompts helped to make the implicit nature of teaching practice apparent.

Table 3.1 shows the overview of the data collection and documentation process for each participant. The data collection method is stated along with its location in the appendices. Five participants took part in interviews and observations and the last participant only took part in the interview.

Table 3.1: *The data collection and documentation process*

Participants	Data collection method	Documentation
1st Grade 12 Electrical Technology teacher	Interview, audio recorded verbal discussions and interactions transcribed verbatim.	A systematic instrument, audio recordings, and transcriptions (see Appendix E1).
	Observation, video recorded verbal discussions and interactions.	Observation schedule and video recordings (see Appendix B).
2nd Grade 12 Electrical Technology teacher	Interview, audio recorded verbal discussions and interactions transcribed verbatim.	A systematic instrument, audio recordings, and transcriptions (see Appendix E2).
	Observation, video recorded verbal discussions and interactions.	Observation schedule and video recordings (see Appendix B).
3rd Grade 12 Electrical technology teacher	Interview, audio recorded verbal discussions and interactions transcribed verbatim.	A systematic instrument, audio recordings, and transcriptions (see Appendix E3).
	Observation, video recorded verbal discussions and interactions.	Observation schedule and video recordings (see Appendix B).

4th Grade 12 Electrical Technology teacher	Interview, audio recorded verbal discussions and interactions transcribed verbatim.	A systematic instrument, audio recordings, and transcriptions (see Appendix E4).
	Observation, video recorded verbal discussions and interactions.	Observation schedule and video recordings (see Appendix B).
5th Grade 12 Electrical Technology teacher	Interview, audio recorded verbal discussions and interactions transcribed verbatim.	A systematic instrument, audio recordings, and transcriptions (see Appendix E5).
	Observation, video recorded verbal discussions and interactions.	Observation schedule and video recordings (see Appendix B).
6th Grade 12 Electrical Technology teacher	Interview, audio recorded verbal discussions and interactions transcribed verbatim.	A systematic instrument, audio recordings, and transcriptions (see Appendix E6).
	No observation	

The adoption of the two data-gathering methods, as indicated in Table 3.1, helped with the triangulation of data. The purpose of triangulation is further discussed in Section 3.8. Interviews and observations provide a complementary synergy in research methods, allowing researchers to triangulate their results and strengthen the study (Patton, 2014). These approaches are especially useful in sectors such as education and sociology, where understanding human behaviour, experiences, and viewpoints is critical (Bogdan & Biklen, 2007). Researchers can achieve a complete and nuanced understanding of their study subjects by integrating the depth of interviews with contextual information gained from observations (Rubin & Rubin, 2011).

3.6.1.1. Measuring PCK

The interviews and observations were graded using a rubric (Appendix C) to assess if the Grade 12 electrical technology teachers had sufficient PCK or if development was necessary. Developing a comprehensive PCK rubric enables more efficient communication and aggregation of results across research (Chan et al., 2019). The rubric was adapted to measure electrical technology teachers' PCK and help identify saturation. Zimmerman's (2015) rubric for assessing the CoRes on electric circuits was extended to three-phase induction motors. The rubric enabled scoring the responses to each question on a four-point scale generated by Park et al. (2011), with scores limited (1), basic (2), developing (3), and excellent (4), and the data was used for quantitative analysis.

The measurement of teachers' PCK was made possible with the aid of a master CoRe (Appendix D). The rubric uses the master CoRe as an example of excellent PCK. This CoRe is based on the content of the curriculum on three-phase motors (DoBE, 2014), and an experienced subject specialist.

The South African curriculum for three-phase motors requires that teachers focus on; the construction of a three-phase motor, the principle of operation of a three-phase motor, the testing of a three-phase motor and three-phase motor starters. The master CoRe has been prepared to focus on the construction, the operational principle and the testing of a three-phase motor.

I created a master CoRe based on the Curriculum Assessment Policy Statement (CAPS) for three-phase induction motors. The document was subsequently passed on to an electrical technology topic specialist who proposed adjustments and additions. Following these changes, the master CoRe was ready for the South African curriculum.

3.6.2. Interviews

Semi-structured interviews are frequently used to confirm data obtained from other sources (Maree, 2019). When using a semi-structured format, a topic of interest is selected along with accompanying open-ended questions that are adaptable and can be changed by the researcher when questioning occurs (Ary et al., 2010). Hence, to create acceptable interview questions and collect data useful for achieving research goals, researchers must have as much experience in the relevant topic areas as possible (Qu & Dumay, 2011).

For my research, semi-structured in-depth interviews with six experienced teachers served as the primary interviewees. The interviews were conducted from May 2023 to August 2023. Each participant chose a convenient location for the interview. Each interview was audio recorded and lasted on average 45 minutes, with the participants given time to reflect on their responses. The CoRe adapted by Coetzee (2018) was used to interview the participants (see Appendix A). The questions in Appendix A were formulated to address my research questions on PCK. Each question asked addressed a specific PCK component, which gave me information on the participant's pPCK. After conducting the interviews, the researcher reflected, took notes, and transcribed the interview. To answer the first sub-question of the study *(How can electrical technology teachers' pPCK of three-phase induction motors be described?)* interviews were used.

3.6.3. Observations

An observation is the systematic practice of recording the behavioural patterns of persons, items, and occurrences without necessarily questioning or engaging with them. (Maree, 2019). When a researcher takes field notes about the behaviours of individuals and activities at a study place, this is known as qualitative observation (Creswell & Creswell, 2014). The researcher documented the activity at the research location in these field notes in an unstructured or semi-structured manner (Creswell & Creswell, 2014; Maree, 2019). The second sub-question of the study *(How can electrical technology teachers' ePCK of three-phase induction motors be described?)* was addressed in this study using lesson observations to examine how teachers revealed their PCK.

For this study, five observations were conducted. The observations took place between May 2023 and August 2023. Each participant chose a convenient location for the observation. Since the observation had to be video recorded, the participants opted for using a classroom or a workshop. Before the observations began, a video recorder was set up in front of the class with a clear view of the whiteboard or any other board in the participant's working space. The setup of the video recorder in front of the classroom meant that no learners were to be recorded as that would contravene the ethical agreement. The video recorder also pictured other teaching media, such as the projector screen, real motors used for demonstrations, testing equipment, and charts. An observation instrument was used to record teachers' ePCK during the lesson (see Appendix B). Based on the teacher's explanations, definitions, questions asked and the usage of the teaching media, a mark was given on the appropriate PCK component in the instrument. This mark helped to identify the teacher's enactment of his PCK. The teacher's observations and interview responses were compared and analysed (see Section 4).

3.7. DATA ANALYSIS AND INTERPRETATION

Qualitative data analysis is one of the most crucial elements in the qualitative research process since it helps researchers make sense of their qualitative data (Leech & Onwuegbuzie, 2007). Instead of emphasising statistical significance and the correlations between variables, the qualitative analysis concentrates on the importance of experiences and acts (Ngulube, 2015). After the organisation and preliminary analysis of the data, they were classified according to the PCK components listed in Table 2.1. During the interviews, the prompts in Table 2.2 were used to answer the research questions(i.e. for interviews, sub-question 1 and for observations, sub-question 2), and the participants' answers were organised according to the PCK components in the left column. For observations, the prompts in the right column aided me in recognising and reporting on the relevant PCK component. By reporting the data in terms of the PCK components (Table 2.1), I could describe teachers' pPCK using interviews to address the first sub-question and ePCK using observations to address the second sub-question and compare their pPCK and ePCK to address the third sub-question *(How do electrical technology teachers' pPCK and ePCK of three-phase motors compare?).* The interpretation and scoring were done sorely by the researcher with the aid of the master CoRe.

3.7.1. Analysis and interpretation of the interviews

Data analysis in qualitative research will occur concurrently with other aspects of building a qualitative study, namely data collection and writing of results (Creswell & Creswell, 2014). Qualitative analysis is a complex and nonlinear process that is typically performed immediately or concurrently with data gathering through iterative, recursive, and dynamic processes (Ary et al., 2018).

The first step in assessing qualitative data is to become familiar with it and organise it to easily access it (Ary et al., 2018). First, the researcher should be acquainted with the data, for example, by reading and rereading notes and transcripts and listening to audiotapes. Because qualitative data are dense, it is important that some are discarded and the focus is placed on the data needed (Creswell & Creswell, 2014). Hence, rereading your notes and listening to the interview tape is important.

After becoming familiar with the material and organising it for simple retrieval, you may begin the coding and reduction procedure. Coding helps to develop a storyline and a theme for the study and helps the writing to become consistent (Stuckey, 2015). A preliminary examination of the data, notes and initial codes concerning the PCK of electrical technology teachers was conducted and identified. The CoRe-prompt tool simplified the coding process as data were initially organised according to the PCK component relating to the questions asked during the interviews. In this study, emergent coding was used as text had to be read, and audiotapes had to be listened to several times for concise analysis as recommended by Maree (2019).

The final step of interpreting and representing the findings entailed thinking about the participants' words and actions and extracting crucial insights from them (Ary et al., 2018). Interpretation is extracting meaning, conveying a story, and constructing credible explanations (Ary et al., 2018; Creswell & Creswell, 2014). After all discussions with the supervisor regarding the changing and re-coding were completed, themes were defined to present the findings logically and concisely. For the interviews, consistent reading and reflection on the process were conducted to ensure that the writing was consistent with the themes. The master CoRe (Appendix D) was used to measure the PCK of all six participants. The master CoRe was developed with the aid of an electrical technology subject advisor.

3.7.2. Analysis and interpretation of the observations

The researcher took field notes during the observations. These annotations improved the first interpretation of the data. The video and audio recordings of the five observations were coded, processed, and interpreted separately. Because the observed classes were from the same teachers who were interviewed, each observation was reviewed in tandem with the individual participant's interview to enhance the analysis and interpretation of the data. Each observation was coded, analysed, and interpreted with the aid of the CoRe-prompt to simplify the process.

Because codes were identified during the interview phase, it was necessary to study notes and watch video recordings to organise the data according to the specified codes. The codes identified during the interview phase made it easy to identify actions related to a specific code during observations. The CoRe-prompts were useful in identifying the actions that belonged to a specific PCK component during observations, making it easy to assign it to a specific code.

After rewatching the video recordings of each observation, assigning actions to a specific code and identifying the PCK components during observation, data reduction took place and unwanted information was discarded. Interpreting and presenting the findings using the adapted rubric (Appendix C) has become easier.

3.8. STANDARDS OF RIGOUR

When conducting qualitative research, rigour can be improved by addressing the credibility, transferability, dependability, and confirmability of the study (Ghafouri & Ofoghi, 2016).

3.8.1. Credibility

Credibility can be defined as the accuracy and validity of the findings (Ary et al., 2018; Ghafouri & Ofoghi, 2016). A qualitative study is exposed to bias because of the reflections of the researcher (Suryani & Utami, 2020). To enhance my research's credibility, I used triangulation and prolonged engagement with the data by gathering data from interviews and classroom observations supported by the presentation of the data using detailed descriptions and minimal descriptors. The data gathered during the interviews were confirmed by the data gathered during the observations.

3.8.2. Transferability

Transferability means that the results of the current study will be the same as those of similar studies conducted in the past and that the results of this study will be applied to future research (Ary et al., 2018; Ghafouri & Ofoghi, 2016). In this study, I ensured that the observations made in the classroom and throughout the interviews provided rich descriptive information that could be compared with previously published studies to ensure the transferability of qualitative research.

3.8.3. Dependability

For a qualitative study to be dependable, independent researchers must anticipate some unpredictability since the study's context varies (Ary et al., 2018). I used an audit trial because it allows others to determine how decisions were made and to evaluate the special circumstances. Another method used was to show consistent findings in different contexts. This was achieved by interviewing and observing teachers in different areas. The data gathered from these teachers were similar even though they taught learners from different backgrounds.

3.8.4. Confirmability

The term "confirmability" refers to the extent to which other people concur with the research findings, as well as the validity of the researcher, an analysis of circumstances in which there is disagreement, and a precise explanation of facts (Anney, 2014; Ary et al., 2018). Audit trails and triangulations were used to organise data and ensure that the data were more descriptive to enhance confirmability. This ensured that I was less biased in my reflections on my study.

3.9. ETHICAL CONSIDERATIONS

Ary et al. (2018) identified four ethical issues to be addressed by a qualitative researcher. These issues include the type of information gathered, researcher-participant interaction, reciprocation, and securing authorisation to perform the research (Ary et al., 2018).

3.9.1. The data

A particular ethical issue may arise because of the qualitative researcher's extensive and personal interactions with the participants and the research location (Ary et al., 2018). Since the data collection procedure involves interviews and observations, during the interviews, I ensured that only information relating to the interview was recorded (i.e., interview questions and responses to the questions). This was done by explaining the interview requirements to the teachers before recording. For observations, video recordings of the lessons were made, and after the usage of the recordings, they will be stored at the University of Pretoria where they will remain for the next ten years.

3.9.2. The participants

After spending significant time observing or interviewing participants, the researcher's connection with them may gradually shift from that of the researcher and participant to that of a friend (Ary et al., 2018). Maintaining a professional relationship is essential to ensure that emotions do not play a role in reporting. To uphold the ethical principles, it was explained to the participants that there are no incentives, their identities will be kept confidential, and participation is voluntary. The study posed no harm to the participants. However, there was a minimal risk that participants felt criticised for their conduct or the number of methods they used during lessons, and they may have felt apprehensive while their lessons were video recorded.

3.9.3. Benefits, consequences, and reciprocation

There are no direct benefits or consequences for the participants in this study. Because of the study, the participants may become aware of some of the PCK components they overlooked. The questions during the interviews became useful to them and beneficial to the development of their pPCK and ePCK. After the final submission and comments, participants and schools that requested a copy of the final study report will obtain one.

3.9.4. Permissions

I obtained ethical permission from the University of Pretoria's Ethics Committee to guarantee that the research was carried out ethically. Before the study began, consent and assent papers were provided to teachers, parents, and learners to ensure that they were aware of the study and its implications. According to the forms, participation is entirely optional, and withdrawal is permitted at any moment. Names will be kept secret. Only information relevant to the study topics was gathered during the interviews and classroom observations. The study method followed stringent guidelines established by the ethics committee. The study began after receiving authorization and consent from the Ethics Committee, the Department of Basic Education, and the schools involved.

3.10. SUMMARY

In summary, an interpretivist paradigm was selected to guide this study. In this study, a single case study with the qualitative research approach was engaged. Quota sampling, a non-probability sampling technique, was used to select participants in and around Gauteng. It was used because it is faster and easier than probability sampling techniques and does not require a sampling frame or the strict application of random sampling techniques. Semi-structured interviews and observations in the classroom were used to study electrical technology teachers' pPCK and ePCK. Qualitative data analysis helped the researcher make sense of the qualitative data by classifying them according to the PCK components, as shown in the conceptual framework. Standards of rigour were discussed, and methods for improving the study's credibility were also mentioned. Finally, the four ethical issues to be addressed by qualitative researchers are explained in conjunction with the requirements of this study.

4. CHAPTER 4: RESULTS AND DISCUSSIONS

4.1. CHAPTER OVERVIEW

In the preceding chapter, I described and justified my choice of methodology based on the study's objectives, research questions, and theoretical framework. In this chapter, I present and discuss the outcomes of the interviews I conducted with six Grade 12 electrical technology teachers about their pPCK and how they performed it during five classroom observations by the same teachers. This chapter is organised into six cases to present an analysis of the CoRes data collected from interviews and classroom observations of each of the six participating teachers. The transcription of each interview is presented in the appendices, and an analysis of each interview with the aid of observation videos is presented in this chapter as a comparison between the interviews and the master CoRe. Tables 4.1 – 4.6 show a summary of the competencies of the teachers in the TSPCK components. The data and findings in this chapter will help address the key question of this research: How do electrical technology teachers' pPCK and ePCK of three-phase induction motors manifest in the classroom? A master CoRe (Appendix D) was created in the preceding chapter to assist in the study of electrical technology teachers' PCK. The PCK, as described in the master CoRe, was considered exemplary in all components; thus, teachers' skills were assessed using the master CoRe.

4.2. TEXTUAL STRUCTURE FOR INTERVIEWS AND OBSERVATIONS

In this section, I discuss the interviews and classroom observations. This study employed a rigorous approach that included six in-depth interviews with teachers and five classroom observations in a variety of educational contexts. The interviews provided a forum for teachers to share their thoughts, experiences, and pedagogical theories, thereby shedding light on the complicated fabric of their teaching approaches. Observations in the classroom, on the other hand, provide a real-time peek into the actual application of these pedagogical techniques, capturing the intricacies of teacher-student relationships, instructional tactics, and the overall classroom atmosphere. This integrated method strives to give a full and nuanced awareness of the complex relationship between the teachers' theoretical knowledge of education (pPCK) and its practical implementation in the classroom (ePCK).

Figure 4.1 illustrates the structure used for reporting on the interviews and observations.

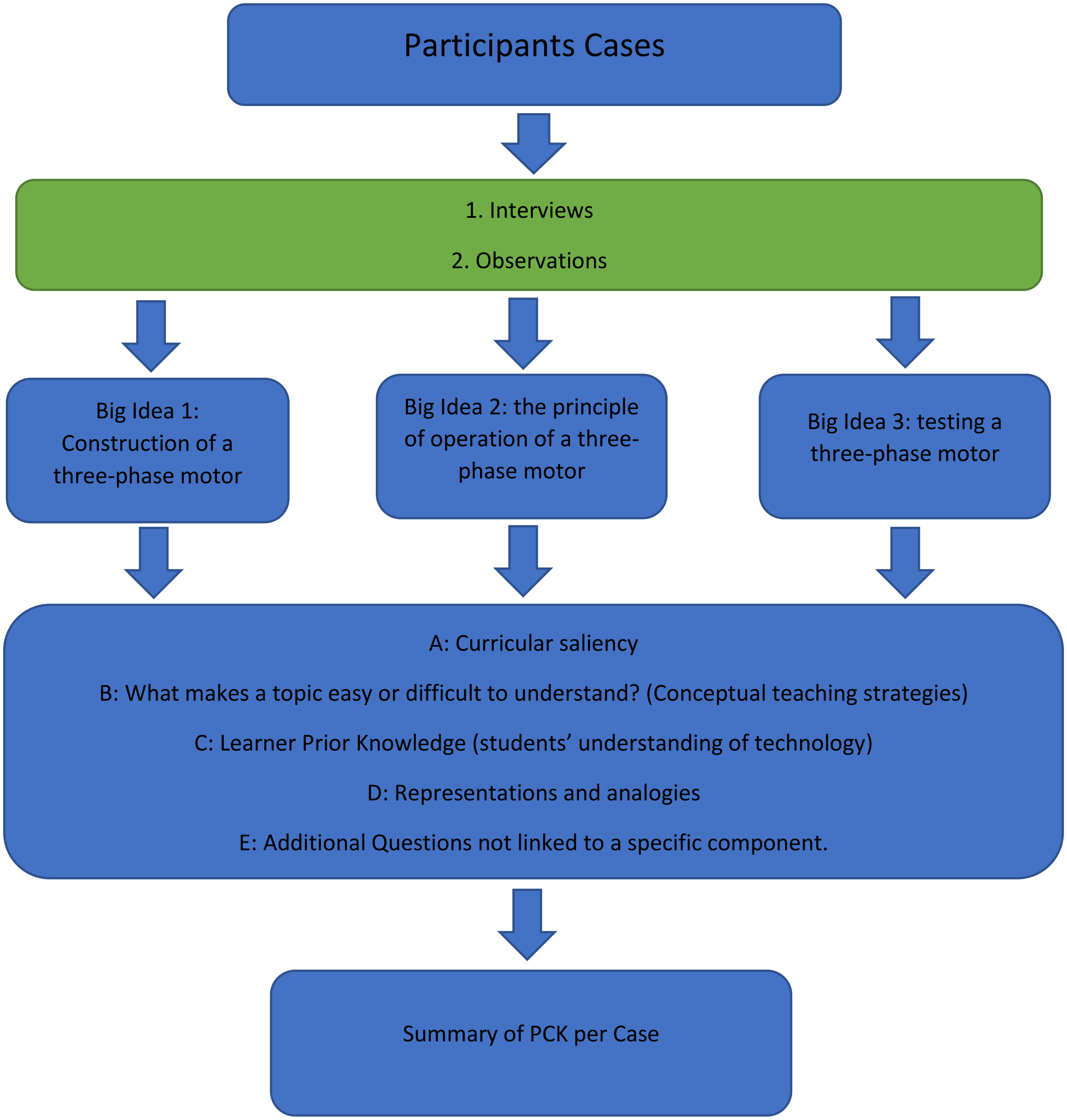


Figure 4.1: *Structure for reporting on the interviews and observations*

In my structure, I initially focus on the interviews and report on the participants' discussions according to the three big ideas. Secondly, I report on each participant's observation according to the three big ideas. Then lastly, I summarise the participant's interview and observation by comparing the two.

4.3. CASE 1 – Participant 1

Table 4.1 below, represents the summary of participant 1 scores from the interview and observation. The participant's scores are compared to the master CoRes and then used to determine whether the participant has sufficient PCK or insufficient PCK.

Table 4.1*: Participant 1 interview and observation compared to the master CoRe.*

	Interview				Observation			
Component prompts	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Knowledge and skills related to curricular saliency			**X**				**X**	
Knowledge and skills related to conceptual teaching strategies		**X**				**X**		
Knowledge and skills related to students' understanding of technology			**X**			**X**		
Representations			**X**			**X**		
Questions not related to a certain component	**X**				**X**			

The "X's" in the table represent the scores attached to a specific PCK component based on the interview and observation discussions from Participant 1.

4.3.1. Interview 1

The interviews will be discussed next, organised into subheadings that correspond to the component prompts shown in Figure 4.1 and Table 4.1.

Curricular saliency

In this section, I report on Participant 1 and his curricular knowledge and its influence on learner achievement.

Under curricular saliency, Participant 1 displayed some developing PCK under the first big idea (i.e. the construction of a three-phase motor), when suitable subordinate concepts were selected and connections to the first big idea were demonstrated. This is evident from the following statement:

[N]ow the introduction of three-phase motors, therefore, came with one of the advantages that *[sic]* the three-phase is able to do, which is self-starting. Now it means we can introduce the formation of the three-phase system, which is two construction *[sic]* such as the star connection and the delta connection. Then now that we have the start and the delta connection, therefore, the three-phase induction motors were able to operate under that supply. That is the introduction of the three-phase and how they came about with the advantage of self-starting. Then from there, we are looking into there are construction. Now the construction with accommodate is *[sic]* two connection that I've already added, which is the three of the start connection and the delta connection.

Excerpt 4.1: What learners need to know about the construction of a three-phase motor

The participants' explanations also include evidence of conceptual scaffolding/sequential developing knowledge for the first big idea., This is evidenced by the following statement:

So now that is why it is important because now *[sic]* when we talk about the single-phase motors, we talk about smaller applications as compared to three-phase motors. Now the three-phase motors are the motors we are expecting them *[sic]* to convert or to work at a level of large amount of energy. So now for an example, let's look at the applications of the three-phase motors. Now with three-phase motors, we talk about pumps.

Excerpt 4.2: Methods of Scaffolding Learning

The above statement suggests that the participant has a developing knowledge of the first big idea. However, the participant showed a lack of understanding of the last two CoRe Prompts (see Appendix B) regarding curricular saliency, as the participant did not answer what was asked. The indicated pre-concepts are inappropriate for the big idea, and the placement of concepts is irrational. The participant gave responses like *"Uh, already as I have alluded, I believe that the practical examples which lead to a* *real-life situation where they are used or they are in contact with, but at some point you find that most of our learners were not aware, that the minute you are able to construct an example that is related to their daily life situations where they are in contact with the use of these motors, but as you find that they were not aware of the use of them"* and *"Basically, it will be about the introduction of the protective devices."* These responses were recorded for prompts A1 and A2 (see Appendix B), and the participant continued to add other irrelevant information to the responses.

For the second big idea (i.e. The principle of operation of a three-phase motor), important subordinate ideas are neglected, although those that are identified are mostly correct. The participant notes that *"the first step of the principle of operation of the motor is to connect the motor to the three-phase supply."* This is an indication of one of the correct answers from the master CoRe (see Appendix D). Other relevant responses were not recorded for this prompt. Less is done for prompt A2 because the stated explanations imply that there is no logical relationship between the subordinate concepts and their relevance to the bigger ideas that follow sequentially.

For prompt A3, the identified pre-concepts are those necessary for understanding the present core idea. This is evident in the statement: *"I believe that by now, it will be only the terminology of [sic] understanding from the previous topics, principles such as the mutual induction, how mutual induction is achieved."* Mutual induction is a concept that is required for learners to understand the principle of operation of three-phase induction motors. The participant also mentioned self-inductance as a concept related to magnetism. The concept was presented in the following statement: *"In an event where the conductor is a stand-alone coil, it will expand and allow the current to flow. That's the principle of self-induction."*

For the last prompt (A4) on curricular saliency in the second major concept, there is evidence of understanding regarding ordering and structuring. Participant 1 used responses that were meant for the first big idea. These responses present a sequencing, as they are interchangeable between the first and second big ideas. The evidence is presented in the following statement:

> [W]hat I need to consider now is, there is the longer the motor is connected to the supply, the motor has a tendency to develop heat. Now, the sooner the motor develops heat, *[sic]* now we start to talk about the losses. Now, we talk about too much current in turn from the supply, and therefore, that is when now, we need to talk about protective device *[sic]* that need to be put in place.

Excerpt 4.3: Scaffolding for the Operational Principle

In the above extract, the participant mentions the development of heat in a motor, which is an example of losses in a motor. Losses are one of the reasons given in prompt A4 on the first big idea. The participant further provided a means to prevent the development of heat in the three-phase induction motor by using protective devices. Protective devices are usually discussed at a later stage in the chapter when learners know more about three-phase motors.

In my third big idea, the participant identified subordinate thoughts that focused on grasping concepts while testing a three-phase motor. Subordinate ideas comprise a comprehensive set of topics to be taught. This is evident from the following statement:

[A]fter that, we come *[sic]* to check if the motor is insulated. Now, insulation, what are our intended objectives? Our intended objective under the insulation resistance test is to check the insulation resistance, check the insulation resistance between the terminal *[sic]* and earth, *[sic]* between the terminals themselves. If they are insulated, there is no way they can make contact with one another.

Excerpt 4.4: Scaffolding for testing of a three-phase motor

In the above paragraph, the participant describes the tests to be performed, which demonstrates the participant’s pPCK of the testing of a three-phase motor. A teacher's pPCK is the cumulative and functioning instructional topic knowledge of a specific teacher, which facilitates interactions while teaching and learning in a classroom context (Shulman, 1986).

Other points made by the participant under prompt A1 in the third big idea are invalid and demonstrate the need for personal development to improve teachers’ pPCK. The participant says, *“In most cases, the motor can be connected in [sic] star in order to run in delta [sic] because of [sic] the star can accommodate the high-starting current, can accommodate the self-starting.”* This statement is false, and it is from a topic that provides scaffolding from the previous chapter. If it is not properly understood by the learners, it leads to more misconceptions about three-phase motors. The participant further states that *“the delta can deal with the high voltage because of [sic] in most cases, you can observe that delta [sic] connection doesn't have a neutral point, whether the star connection has a neutral point.”* This statement indicates the participant’s misconceptions of voltage.

The reasons given in the next prompt (A2) are confined to the overall advantages of education. The participant does not show an understanding of the question asked. This is evident from the following statement:

[T]he star and delta connection is for learners to know that most machine *[sic]* in *[sic]* household environment *[sic]* and they must know one of the questions such as why must you use a star to start a motor? Remember, the star has a star point and now it's a domestic application or in industry. So, there is a star connection *[sic]* brings about the balance in the system of connection, whereas the delta connection doesn't have a neutral point. So, now, which *[sic]* it deals mostly with the *[sic]* high voltages.

Excerpt 4.5: Objectives of the three-phase motors

The starting of a motor is a concept that should be addressed at a later stage. According to the expert, CoRe learners need to be taught the basic function of a motor, how to use the test tools, and how to interpret the test results. The participant later mentions that *“so that one can understand and so can interpret and can also be able to can troubleshoot in an event the motor has a problem or damage.”* This statement represents some concepts that learners must know under this PCK prompt. Because the explanations presented ignore concerns, such as scaffolding/sequential development, this demonstrates some basic PCK that requires development.

Some pre-concepts that are directly connected to important notions were left out for PCK prompt A3. The participant narrowed their attention to only one idea related to curricular saliency. The participant stated *“The major concept is safety. For them [learners] to understand safety. Talk about protective devices, talk about the safety of the equipment, we talk about the safety of the user of the equipment.”* The statement explains only one requirement for the prompt which compromises the participant’s pPCK on curricular saliency.

For the past prompt on curricular saliency, the participant shows a good understanding of the concepts as he mentions that *“The only thing that we, we haven't arrived at yet is the issue of the starters, which of them I refer to not [sic] the general knowledge people. It means that there are practical applications to say that the starters gives [sic] instruction to motors on how to operate when connected to the supply.”* Motor starters are taught at a later stage in the field.

What makes a topic easy or difficult to understand?

The ease or difficulty of learning a topic is affected by several factors, which can be classified as content-related, cognitive, and contextual. For this study, I focused on content-related issues and teaching methods.

For the first big idea under this heading, the participant showed good knowledge of the challenges faced by learners and teachers. The participant states *"The major difficult part might be the theory part, [sic] most cases for learners to understand because the major barrier we have in teaching, the difference between the subject, myself as an educator, also learners, which is the language."* Language usage involves concepts that learners and teachers find difficult to understand as they are not part of their daily lives.

The participant showed some understanding of the concepts that are challenging for learners in the second big idea. The participant states that *"the difficult part of teaching is the principle of operation. It is only when the learner will fail to understand the chronological application of these motors because what it needs to be given as a jurisdiction, in this case, we need to mitigate the information to say it has to open chronologically, step-by-step."* The operating principle is a step-by-step description of how a motor achieves its rotation (Bird, 2017). Understanding the operational principle depends on several factors. These factors include an understanding of electromagnets and how two magnetic fields moving in opposite directions can generate a force. The factors mentioned are embedded in the principle of operation; thus, the participant only mentioned the general toping without specifying the core problem.

In the third big idea, the participant noted that learners are experiencing difficulty with the use of measuring equipment. The evidence is as follows:

> [W]ell, the difficult thing about the testing of a three-phase motor is that the learners do not know how to use the meters, they do not know which meter to select when conducting a certain test. For example, if you test for continuity, they do not know which meter they must use and which scale they must select. When measuring the insulation resistance, which meter must they use and which scale they must select as well? So that is what I consider a challenge for them, mostly.

Excerpt 4.6: Challenges of testing a three-phase motor

The lack of understanding of how to use the meters includes the inability to interpret the readings on the meters during a test. However, the participant only focused on generic information and not on the specific aspects that learners are struggling with.

Learner Prior Knowledge

Learners' prior knowledge refers to their understanding, abilities, and experiences before interacting with new educational content or activities.

Under the construction of the three-phase motor, the participant stated, *"The misconception in most cases that learners, they [sic] are failing to align themselves to the terminology used, because if I were to be honest with you, even when you were to ask questions and listening [sic] to that response, you discover that the learners do have knowledge, but because of they are not comfortable with the instruction of being English, they therefore fail to express their understanding."* It seems that learners have a problem with the terminology used in the subject. This is an identification of fundamental issues that are typically not recorded as topical misconceptions.

In the next big idea, the participant noted that *"The misunderstanding the learners often have actually [sic] is for them to mention the step by step. I mean, that is the only thing they are messing up in most cases."* The response is poorly formulated as it does not describe a misconception. The participant adds *"But for them [learners], we need to understand that it [the motor] must be connected to the supply and also to consider that there might be losses that will occur."* The teacher does not indicate any misconceptions presented by the learners.

For the third big idea (testing of a three-phase motor), the participant noted that readings were recorded incorrectly, and learners failed to include the SI unit next to the recordings. This is evidenced by the following statement:

> [T]he real misconception that they make is when they do not understand the terminals or they don't understand how to troubleshoot the terminals, and then how to track them, and also the recording of the findings. For example, *[sic]* you are doing continuity, they will just write numbers, if they do understand, they will just write numbers. Not taking into consideration that they must use the scale; they must use the prefix. You can just find that the insulation tests that have prefixes as mega or giga ohms, which, at the end of the day are the *[sic]* intended to inform the objectives of the testing.

Excerpt 4.7: Misconceptions about testing a three-phase motor

The participant implied that learners believe that the recording of the test results does not need SI units to be correct, numbers alone are fine.

Conceptual Teaching Strategies

Conceptual teaching strategies offer an educational perspective change, moving beyond memorising facts and procedural learning.

For the first prompt (D1) in the first big idea, the participant is quoted using the direct instruction method as evidenced in the statement *"mostly an instructional method, you just instructed them to say that, remember that the motor consists of two major parts, being a stator part and the rotor part."* The participant shows a sound understanding of the teaching strategy required to ensure learners understanding. The participant explains how the strategy will be used by adding *"Now, when constructing the motor, now [sic] what are the considerations here is to consider what I have alluded as an introduction to the topic as the three-phases supply, and then now the motor would produce this mechanical rotation."* The above statement explains how the participant used direct instruction as a teaching strategy in the classroom. The only challenge noted in this PCK prompt is that the participant focused on using only direct instruction as a teaching strategy. Not every learner learns in the same manner, and using a single teaching technique in the classroom may be harmful to certain learners (Wibowo et al., 2020).

The participant posed questions related to conceptual knowledge, which led to the constructive development of concepts for the second prompt (D2). These questions and statements are noted in the following excerpt:

> [W]ell, what is important is for me to get to know what do *[sic]* they already know. *[sic]* What do they understand about the three-phase motor to start with? And then now what is an advantage of using a three-phase motor over a single-phase motor? and then also the other construction of the motors I would like to get from them if they know about the parts that constitutes or builds *[sic]* up a motor.

Excerpt 4.8: Questions to be asked during a lesson

Some questions are missing from the above interview extract. Although the participant is asking important questions, the participant needs to ask questions that provoke CT.

Regarding the second big idea, the first prompt on teaching strategies was not well understood by the first participant. The participant implied using direct instruction. This is evidenced in the statement: *"The operation actually in most cases is often interesting when you refer to them to the practical application of it, where you connect it to the supply and then it's the point where they then understand how the motor operates, the production of rotation, and all those things."* This statement refers to the participant instructing learners on what to do during a lesson. Although it is not bluntly clear, the use of a single teaching approach may lead to more learner misconceptions.

In the second prompt on the second big idea, there is no indication of questions to enhance understanding of concepts. Some questions asked are not linked to the big idea and thus are not appropriate for the PCK prompt. The questions noted by the participant are *"One is to what considerations will we give to for one to operate the three-phase motor? Yes, consideration [sic] that as what should be a supply for the three-phase motor? And now when working with the three-phase supply, what are the voltage ranges of the three-phase supply?"* questions like *"What should be a supply for the three-phase motor?"* should have been asked earlier during the construction when learners were being taught about the nameplate of the motor.

The first prompt concerning teaching strategies in the third big idea is practical. Levels of representation are proposed to reinforce the concepts with explanatory remarks. This is demonstrated by the following statement:

> [T]he testing of the motors will use the panels for three-phase motors. We use the motors, we expose to them, we take the three-phase motor, so we put here, we open it, show them the terminals, we show them how this must be done, and then in a *[sic]* visual aids, such as videos that are in place, such as found in YouTube, expose to them, we play those videos for them, so that they can see what is intended about the motors.

Excerpt 4.9: Teaching strategies used when testing a three-phase motor

The participant again explained how to use the teaching strategy without explicitly stating it. From the above paragraph, we can deduce that the participant is going to use direct instruction. Each teaching strategy is most useful when paired with another.

In the second prompt under the third big idea, the participant asked questions and gave statements that promoted rote learning. The participant's response to the question is noted in the following excerpt:

[W]hen teaching about testing, remember, as I said, the cognitive levels, we start with the cognitive levels. Which will be to *[sic]* which instrument should be selected to conduct a certain test? Then the lower, uh, the lower order question is, are the types of tests to be conducted? What types of tests are typically in a motor? And what instrument must be used to conduct those tests? And what are the intended objectives of connecting these tests?

Excerpt 4.10: Questions asked when teaching learners about testing a three-phase motor

The basic questions which are posed in the statement are *"Which instrument should be selected to conduct a certain test?"* and *"The types of tests to be conducted?"* the first question is too broad, and the second question does not evoke critical thinking skills.

Representations and analogies

In the first big idea, the participant showed a deep understanding of the teaching media needed to enhance learners' comprehension of the construction of a three-phase motor. The mentioned representations are sufficient to ensure learners' comprehension of the content. The participant stated *"Often we use textbooks to refer to them that this is what we're talking about. They see the pictures of the motor."* The participant also demonstrated sound knowledge of how to use the representations mentioned. The following statement confirms this:

[T]hey see the construction of the motor so that now *[sic]* we also mention the advantages. Also, taking into consideration the principle of operation of the motor, which is the one that I refer to as an instructional, because of *[sic]* it consists of the steps for a motor to operate. It has to be connected to the supply. Now, the supply to the three-phase supply. Therefore, either might be connected in a *[sic]* form of a star or a delta, which I will give you later when I'm doing the motor testing. Now, in this case, now *[sic],* when you are interested in the principle of operation to say, now, remember, we said the motor consists of two major parts, the stator part and the rotor part. So now, this is how it works, the stator part is the one that is connected to the AC supply.

Excerpt 4.11: Representations used for the construction of a three-phase motor

The participant mentions the parts of a motor that will be easily identifiable by the learners when using the pictures in the representations. The use of representations will help learners understand the topic.

For the second big idea, the participant described some lesson ideas to relate the various types of illustrations to the concept of operation. The statement *"Now, on this one I will be having in my lesson plan. I'll be my projector screen there, my laptop, and I will be referring to them to the visual pictures that they can see as we talk about those principles of operation."* Show that the participant understands the impact of the representations to be used as the participant further explains that *"we can play the video and pause the video just to check the questions, if they have any questions, just to check with them if they understand, and up to the point, linking with what has been explained already."* These results suggest that the participant had sound knowledge of learning representations, thus informing the development of the participant's ePCK. Research by Puspitarini and Hanif (2019) confirms that teaching media is important in keeping learners interested in the lesson, which increases the chances of learners understanding the content being taught.

For the third big idea, the participant shows a good understanding of the representations needed to promote excellent teaching and learning. The following statement demonstrates that the participant is knowledgeable about testing a three-phase motor, which also indicates the PCK of the participant.

> [T]he media used in this, uh, will be to take motors, physical motors, you put them there, give them screwdrivers, open them, show them the terminals, uh, play the videos so that they can, uh, be exposed or give them meters to do it practically, actually this one, it took *[sic]* most likely interest in when done practically done explaining the explaining.

Excerpt 4.12: Representations used for testing a three-phase motor

The participant not only identifies the representations to be utilised but also indicates how the media will be used. Consequently, a suitable collection of representations sufficient to facilitate concept clarification is supplied.

Additional Questions not linked to a specific component.

For the first big idea, the participant did not provide any form of assessment. This is evident from the following statement:

[U]nfortunately, or on this one, because of *[sic]* it's more of *[sic],* it's more the construction and the principle of operation is more likely the principles, because of *[sic]* the principles means *[sic]* the guideline. There is no way you can introduce someone's understanding, but they are always giving me research for them to memorise.

Excerpt 4.13: Assessing the construction of a three-phase motor

The participant declares that one cannot assess the construction of a three-phase motor. Assessment is critical in vocational topics because it links educational goals with industry standards and assesses the effectiveness of teaching and learning. Teachers may discover areas for development through evaluation, allowing for a more personalised learning experience for learners in skill-based disciplines. One major advantage of evaluation in vocational subjects is its capacity to imitate real-world circumstances for the development of practical skills (Ainley & Rainbird, 2000; Hodkinson, 1994; Le Var, 1996; Smith & Comyn, 2003).

In the second big idea, the participant gives sound arguments for assessing learners. By saying *"The entire topic is based on the principle of mutual induction, will they be able to break down that [sic] because of how we're looking at the angles at which the examiner and they might be able to ask the question?"* The participant gives us examples of how to use the assessment for a better impact on learning. The participant focuses on the use of recent years' previous examination question papers to formulate assessments for learners. It is evident in the statement: *"Now referring to the examiners, I'm referring to the previous years' question papers and other sources we have, but mostly the question papers I'm referring to are within 2020 to 2022 official questions [sic] papers, such as the preliminary examination and November/ December final examination question papers, where these questions are then asked and then they give the learners an opportunity to be exposed to the types of question to expect an exam in a form of those levels that are being addressed as an easy type of question, or as they go gradually to the point when we ask them the difficult questions and then at the end of the day entirely actually objective of the topic."* The assessment of vocational topics emphasises the importance of hands-on experience, problem-solving abilities, and working in various businesses and jobs. As a result, by strengthening employability skills, vocational education and training institutions may better connect their curricula with actual workforce demands (Fitriyanto & Pardjono, 2019). Assessments such as practical examinations, portfolios, and work placements can provide information on how effectively students respond to simulated or real-world employment issues (Bayerlein, 2020). As a result, assessing students' progress in vocational topics helps them build their overall skills and preparedness to contribute successfully to their particular fields.

On the third big idea, the participant again uses previous exam question papers. The 2020 examination particularly for testing of a three-phase motor. This is evident in the statement *"The learners' understanding, uh, will be then assessed by, I mean, that's for them to understand the main objectives of why are we doing testing, why is it acceptable, and what recording should be given. Because they did this one question paper that I liked in 2020 during the COVID time."* The participant shows a sound knowledge of the assessment methods that are effective in testing a three-phase motor. Since testing is a more practical exercise, the participant further states *"I think for the June exam, where they do the PAT paper, they call it a PAT paper. So on that PAT paper, the learners were exposed to the question [sic] were what are [sic] the expected tests, where you are conducting tests in the motor, and also the recordings to indicate the infinity for a [sic] continuity to indicate the resistance for insulation resistance, then, then also to take into consideration the minimum acceptable value, so that now those are a form of assessment that I will use to assess them."* The use of a June question paper that refers learners to the practical activity done in their workshop helps them understand the importance of the topic and prepares learners for the formal examinations that are going to take place.

4.3.2. Observation 1

Participant 1 presented the class in a well-equipped workshop with the most recent training panels provided by the DoBE. Tools, protective devices, transformers, and motor control panels were displayed to all learners to familiarise themselves with. Other older equipment was on exhibit to teach learners how technology evolved. The exhibits in the workshop provide learners with a sense of realism, and learners may interact with industrial equipment, to prepare them for real-life circumstances.

The teaching strategy used by the participant for the duration of the lesson was direct instruction. The learners seemed docile and ready to learn. The participant used questions to assess the learners at the end of the lesson.

Regarding curriculum saliency, the participant showed good curriculum knowledge, as he referred learners to their previous grades. Then proceeded to provide scaffolding by reminding learners of single-phase motors. The participant did exactly what he mentioned in the interviews: differentiated between the supplies of both single-phase and three-phase motors, mentioned the benefits of three-phase motors over single-phase motors, and explained the parts of a motor.

The teaching strategy used was the direct instructional method, as discussed in the interview. However, the learners were not asked questions to improve their understanding of the construction. The use of one teaching strategy proved to be detrimental to learning as learners did not fully participate in the lesson. The representations used by the participant were sufficient, as expressed in the interview.

The participant did not clearly outline the lesson objectives to the learners. This may cause some learners to lose concentration or the teacher to stray off the topic. As demonstrated, the teacher went off-topic and explained parts of a motor that were not from a three-phase motor. Referring to the recording, the participant spoke of the carbon brushes and commutators. However, these are not part of a three-phase motor. This may indicate inadequate content knowledge and a deficiency in pPCK. The participant also mentioned the use of protective devices during the construction of a three-phase motor; however, these protective devices were not taught during the lesson. The participant did not provide practical examples of the construction of a three-phase motor, as discussed in the interview. Learners were not asked questions to arouse their interest in the construction. The participant did not emphasise the use of terminologies, as indicated during the interview as a misconception.

Under the principle of operation, the participant rightfully explained mutual induction as a concept on which the principle of operation is based. This concept is linked to what the participant explained in the interview under the learners' prior knowledge. The participant also explained the supply to be connected to a three-phase motor, which was also indicated in the interview. However, the participant used the wrong motor to explain the principle of operation. This is an indication of the participant's misconception about identifying the types of motors, further showing a lack of pPCK. The educator also displayed a misunderstanding of magnetism. This is evident in the video recording; a reference is made to the two opposite poles that repel each other. Other incorrect references are made about the magnetic field, the Electromotive force (emf), and how the rotor rotates from the magnetic field forces. Electromotive force (EMF) is created in a magnetic circuit via a process known as electromagnetic induction. According to Faraday's law, an EMF is induced in a conductor by a changing magnetic field (Bird, 2017). The participant did not refer to a changing magnetic field and yet proceeded to explain the EMF.

Through the observation, the participant also explained the difference between the synchronous speed and the rotor speed, although this was never mentioned as part of his lesson during the interview. The participant also explained the slippage of the motor, which was not discussed in the interview. As explained during the interview, the participant explained to the learners how to state the principle of operation of a three-phase motor in a step-by-step manner. During the observation, the participant did not ask the questions he was expected to ask, as stated in the interview.

To test a three-phase motor, the participant did not have the expected test equipment to be demonstrated to the learners. The correct motor was also not used to enhance the learning experience. The participant explained the star and delta connections as expected from the interviews. The participant explained that the tests were to be performed as expected. The participant expressed some misconceptions during the presentation by incorrectly explaining the motor losses. The participant then mentioned visual inspections, as expected from the discussions of the interview. He then asked questions related to those discussed in the interviews. The participant again indicated misconceptions about interpreting the reading of the continuity test. The continuity test is meant to check the electrical continuity of the windings to ensure they are not broken. The participant then could perfectly explain the insulation resistance test. During the observation, the participant described a misconception that was discussed in the interview. The first question used as a formative assessment was too broad; making it hard to answer. The remaining questions were answered without many challenges. The participant again showed some misconceptions regarding Ohm's law. With the number of misconceptions recorded, the participant needs some content development workshops to improve his knowledge.

4.3.3. Summary of Participant 1's PCK (Case 1)

Participant 1 provided a clear description of his pPCK through the interview. A description of his pPCK via the teaching tactics, understanding of the curriculum, and grasp of structuring and ordering contributed to understanding how the teacher deals with misconceptions. The master CoRe was useful in gauging the participant's pPCK. Certain aspects like misconceptions and the third big idea (i.e., testing of a three-phase motor) were inadequately discussed in comparison to the master CoRe. These aspects include how to perform the continuity test and the purpose of the test.

The observation helped to describe the participant's ePCK. The participant, through the lesson observation, could express some knowledge described in the interview. Through the lesson observation, scaffolding was provided as the participant referred learners to single-phase motors. The reference provided learners with background knowledge before being taught three-phase motors. The use of scaffolding also displayed the participant's knowledge of lesson sequencing, which improved the likelihood of learners' understanding.

There is a clear connection between the participant's interview and lesson presentation. This connection presents similarities in the participant's pPCK and ePCK. Although certain aspects of the master CoRe were not displayed in the enactment, some were discussed in the interviews. The participant spoke about the tools to be used when testing a three-phase induction motor but did not show the learners how to test the three-phase motor. The usage of a wrong motor also indicated some deficiency in the participant's CK, which indicated inconsistencies between his pPCK and the enactment of it.

4.4. CASE 2 – PARTICIPANT 2

Table 4.2 below, represents the summary of participant 2 scores from the interview and observation. The participant's scores are compared to the master CoRes and then used to determine whether the participant has sufficient or insufficient PCK.

Table 4.2*: Participant 2 interview and observation compared to the master CoRe.*

	Interview				Observation			
Component prompts	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Knowledge and skills related to curricular saliency			**X**				**X**	
Knowledge and skills related to conceptual teaching strategies	**X**				**X**			
Knowledge and skills related to students' understanding of technology			**X**			**X**		
Representations			**X**				**X**	
Questions not related to a certain component		**X**			**X**			

The "X's" in the table represent the scores attached to a specific PCK component based on the interview and observation discussions from Participant 2.

4.4.1. Interview 2

Curricular saliency

In this section, I examine the significance of curricular saliency as portrayed by Participant 2, examining how the participant feels it influences students' learning experiences and prepares them for the challenges of three-phase induction motors.

In the first prompt (A1) of the first big idea (see Appendix B), the second participant's selection of concepts that learners need to know illustrates the conceptual logic linked with the topic (the construction of a three-phase motor), as relevant subordinate ideas are found and linkages to the main idea are displayed in curricular saliency. This is demonstrated by the following statement:

> [B]asically, they should know that a motor is a machine and in most of the *[sic]* cases, when you tell learners about a machine, they first start thinking of an engine. And it's always advisable that you show them what type of a *[sic]* machine are you talking about. So it's always important to have a three-phase motor ready in class so that they can see it, don't *[sic]* only imagine it, but see it. So you tell them that it's a machine and sometimes they might think of something very huge. Then if you have it, it's good because they'll change their mind and see, okay, no, no, no, no, a three-phase machine can it *[sic]* take any size, can be the same size of a single-phase motor. They don't differ that much, they are literally *[sic]* the same, they have the same size, the same shape, and the construction is the same.

Excerpt 4.14: Second participant's concept selection for construction of a three-phase motor

The parts of a three-phase motor and its advantages are also discussed which inadvertently answer a question that is later asked. The participant includes a comparison of a three-phase motor to a single-phase motor by saying *"I'm talking about the single-phase and the three-phase motor. So how are they going to know all the differences? This is where you must explain about the windings. This is where you must explain about [sic] the operation or the uses of the single-phase and the three-phase motor. This is where you must talk about the advantages and the disadvantages of both single-phase and three-phase motor [sic]."* The comparison facilitates learners' conceptual scaffolding and improves their understanding of three-phase motors. Although some concepts are not discussed, the participant showed expert pPCK levels as comparisons between the single and three-phase motors involved aspects in the first prompt.

The arguments provided by the participant in the second prompt (A2) of the first big idea revealed no logical relationship with the big idea. The explanations offered by the participant are more closely related to the second great idea. By saying *"So it is always important for them to understand that the operation, the rotation will happen inside it, and how is it going to happen? That is when we talk about the operation."* The participant shows a lack of understanding of the question or no conceptual knowledge concerning the objectives of the curriculum under the construction of a three-phase motor.

The indicated pre-concepts for prompt A3 are those required for comprehending the current core idea. This is clear from the following statement: *"Number one, it should be the frame, and then the frame being the housing of the motor. And [sic] then we come to the internal part of the motor, where we talk about the laminated iron core inside the motor, where we talk about the shaft, where we talk about the movement of the current inside the motor, and then the other thing that they should know, it's the law of magnetism, we have Lenz's law, we have Faraday's law, we have yes, I think, I think that's that."* The statement above shows exceptional knowledge of the concepts that affect the construction of a three-phase motor. The participant indicated the ability to move learners from the known to the unknown by tapping into their prior knowledge.

For prompt A4 in the first big idea, the participant showed some evidence of knowledge about the sequencing and scaffolding of concepts. In the statement:

> [Y]ou should teach them about the construction of *[sic]* it, or the composition of the motor itself, everything must be taught. I mean, why should you leave something out? Everything must be taught, so that they know it holistically. They should know how does it look *[sic],* what happens, how does it operate, and the advantages and disadvantages of whatever the construction of it.

Excerpt 4.15: Construction of a motor including advantages and disadvantages

The participant further supports the statement by adding *"You cannot start teaching motors, Three-phase motors, before starting with single-phase motors. So, by teaching single-phase motors, you touch everything, because both the motors are the same. So, everything must be touched, everything must be taught."* For a knowledgeable teacher, an understanding of single-phase motors is critical for providing scaffolding, and the same is true for three-phase motors.

For the second big idea (the operational principle of a three-phase motor), the first prompt (A1) was partially understood. The participant mentioned some concepts that are correct when compared with the master CoRe. This was explained in the statement *"Number one, understand the laws about magnetism. Okay. Number two, understand the induction. When we talk about induction, how is EMF induced in the* *coil? Okay. What propels, what is moving inside the motor?"* The participant simply focused on the previous grade's work for the entire question, instead of including new concepts for the current grade. This may indicate a deficiency of pPCK because the content seems to be insufficient which may affect the preparations of the teacher in the topic.

For prompt A2 in the second big idea, the participant showed an understanding of the objectives of the operational principle. The objectives are well outlined and explained. The participant indicates that:

> [W]hen current starts moving, uh, *[sic]* magnetic field is produced. And then, uh, that magnetic field, that is the one that causes the rotation of the rotor. But then, remember, we have the windings of the stator and the winding of the rotor. Now, the EMF starts from the stator. The rotor doesn't have any EMF because the rotor is not connected directly to the supply.

Excerpt 4.16: The process of the operational principle

In the statement above, it is evident that the participant understands the relationship between the magnetic field and the operational principle. The participant further explains the production of a rotational force by stating *"This is where [sic] opposite magnetic field, uh, the MMF is going to force that rotation."* The magnetomotive force (mmf) creates a torque, which forces the rotor to rotate.

For prompt A3 (see Appendix B), the participant selected pre-concepts that were necessary for understanding the present prompt. The participant stated that for learners to grasp the operation of a three-phase motor, they must first understand the *"Magnetic field, laws of magnetism, [sic] induction."* These three concepts are critical for teaching learners how a motor works.

For the last prompt in the second big idea, the participant noted *"nothing"* that should be hidden from the learners under the principle of operation.

In the last big idea (testing of a three-phase motor), the first PCK prompt (A1) the participant displayed an understanding of what learners need to know about the testing of a three-phase motor. Good examples of how to test and the types of tests to be performed were discussed. The participant stated that.

[B]efore you can connect the motor. The first thing that you should do is to test and then we have two types of tests. We have the physical one or the mechanical *[sic].* We have the electrical, uh, testing. The physical one or the mechanical one is to, you know, observe, look at the *[sic],* the motor. Touch it. Check all the components.

Excerpt 4.17: Steps to be taken when testing a motor

These tests must be performed by learners on a three-phase motor. The participant added examples of each test to be performed on a three-phase motor and the purpose for which the tests are performed. By stating that

[C]heck whether there are no broken fins there. There are no broken, parts, any parts, they are no broken fans. Uh, if you're satisfied, there's nothing broken, then the physical part is okay. Uh, on the electrical, you *[sic],* you check whether the terminal box is okay. Then you can take the insulation tester or mega to check the windings, you check for the insulation. You check for insulation resistance. You check for continuity. If you are satisfied with all that, then the machine will be ready for you to use.

Excerpt 4.18: Examples of tests to be performed on a three-phase motor

The participant breaks down the tests to be performed for simple understanding. This breakdown of the tests is a display of an exceptional pPCK when testing is involved.

The arguments provided in the second prompt included evidence of conceptual scaffolding comprehension or sequential development. When working with three-phase motors, the participant knows the necessity of safety. As demonstrated below:

[I]t is always important. Let's say you get a machine. Hmm. Then what you *[sic]* do, you just connect without checking all those things. What if there's a fault? Then that machine will be a danger to you. And, uh, wherever you'll be using it.

Excerpt 4.19: First steps to testing a motor

The participant went on to say that the goal of testing a three-phase motor is *"So it is always important for the safety of the user and the other component."* the statement displays alignment with the master CoRe concerning safety.

In prompt A3 of the third big idea, the participant showed some understanding of concepts that learners need to know before learning about testing a motor. The concept of safety has been stressed further and other concepts that affect the learners' ability to test a three-phase motor have been ignored. As demonstrated below:

[S]afety. It is very important. Remember, these are electrical machines and with electricity safety, it's number one on the list. Find out how safe the machine is. And then that's the first initial point. That's where it should start.

Excerpt 4.20: The importance of safety when testing a three-phase motor

The participant did not mention the importance of teaching learners about test equipment. Explaining how to use the test equipment to the learners might eliminate any misconceptions that learners might have during the lesson, as the multimeter and the insulation tester were used before in the previous year.

For the last prompt on curricular saliency (A3), the participant mentioned that everything must be taught, as the same tests have been performed by the learners in the previous grade under single-phase motors.

What makes a topic easy or difficult to understand?

I explore the synergies that exist between teaching approaches and the understanding of three-phase motors concepts in this section.

For the first big idea, the participant noted an appropriate difficulty related to the construction of a three-phase motor. This is demonstrated in the reasons below:

[Y]ou know what, with a *[sic]* construction, I don't think there's anything difficult except the windings. In most of the cases, when we talk about windings, they don't see them. Yeah. You just see something very closed, something covered when I say closed, I say something covered. When I talk about the rotor of the machine, we need to be covered. You'll never see the windings. So, why not be expecting *[sic]* to see those wires? You will never see those windings. It is just covered nicely covered.

Excerpt 4.21: Difficulties while teaching the construction of a three-phase motor

Although the mentioned difficulty is not similar to the one in the master CoRe, it is an appropriate difficulty that can be experienced by teachers when preparing and teaching about construction.

In the second big idea, the participant displayed a sound understanding of the difficulties faced when preparing to teach the principles of operation. The participant noted the following:

[H]ow does the rotor when it is not connected to any supply rotate? That is very difficult because, in most of the *[sic]* cases, learners don't understand if they didn't *[sic]* understand the principle of magnetism and induction. How current is induced, how *[sic]* magnetic field is produced, *[sic]* then it's the problem. And it is going to be difficult for them to understand the induction of EMF through the stator. Remember the stator it's totally *[sic]* not connected to the supply. So it becomes a challenge in most of the cases that, the rotation, how is it going to move? How is the rotor going to move?

Excerpt 4.22: Difficulties faced when teaching the operational principle of a three-phase motor

Concerning the master CoRe, the participant came to the same conclusion regarding the difficulty of preparing and teaching the principles of operation. The master CoRe notes that “Learners find it difficult to understand how two magnetic fields moving in opposite directions cause a force.” This is similar to the participant’s argument regarding the principle of magnetism and induction in the extract above.

In the last big idea, the participant noted the use of measuring instruments as the challenging part of preparing for teaching. Noted in the statement below, the participant mirrored the views of the master CoRe.

[R]emember when you test, let's say you test a three-phase motor, and then you must first check on the nameplate. You check the voltages, you check the current and then when you test for insulation and resistance, all the time, you must double your voltage on the meter, on the megger. That's the first thing that, uh, learners should know. And, uh, when you go check for your resistance, your continuity actually, your meter should always be on, on the resistance scale. So in most of the cases, it’s difficult because learners don't consider such things. They just want to test and nothing else without actually taking the values that they’re measuring.

Excerpt 4.23: Challenges in using measuring instruments

Learners have difficulty using meters, and they do not consider the scale to be selected, which leads to incorrect readings by the learners.

Learner Prior Knowledge

In the first big idea, the participant gave a different misconception to that found in the master CoRe. Evidenced below:

[A]s I said, they will be thinking of an *[sic]* engine of a car, and they'll be thinking of something very big. Okay. Something very big. No, no, no, no, we expect any size. From motors, we expect any size.

Excerpt 4.24: Misconceptions by Participant 2

According to Participant 2, learners find it difficult to understand what constitutes an electric motor. Although a different misconception, the evidence points out that learners struggle with the basics of construction, the identification of parts as expressed by the master CoRe, and the findings from this interview.

Focusing on the principle of operation, the participant identified issues comparable to those discovered in the master CoRe, indicating a clear comprehension of misconceptions and their causes. As indicated by the following statements:

[T]hat the rotor must be connected to the supply. When you *[sic],* you switch your plug on, uh, you press your start button. Then, then *[sic]* the rotor will start rotating because it's connected to the supply. When, when it is totally not connected.

Excerpt 4.25: Misconception about the operational principle

Learners assume that the current is directly applied to the rotor, causing it to rotate. This assumption implies that learners do not fully understand the principles of magnetism.

Under testing of a three-phase motor, Important well-documented misunderstandings linked to conceptual comprehension are covered, although not in totality. The participant omitted learners' understanding of the contrasts concerning the continuity test and the insulation resistance test. The participant stated that *"the windings, in actual fact, they would only want to check or test for continuity, not insulation resistance and not insulation resistance between windings, not insulation resistance between the windings and earth."* The statement not only describes the lack of understanding of the electrical tests by the learners but also the disregard for safety as the insulation resistance test can determine the safety of the motor for usage.

The participant also noted that learners understood the differences between the continuity test and the insulation resistance test, which seems contradictory, because, as mentioned above, learners only perform the continuity test. That means the insulation resistance test is not important. When asked if learners know the difference between the two electrical tests, the participant said *"Yes. You tell them, especially, it is so tricky because, uh, remember the windings of the motor, if you look at them, they're just laying on top of each other."* These data show dissimilar traits when compared to the master CoRe.

Conceptual Teaching Strategies

As education adjusts to the needs of the new curriculum, conceptual teaching methodologies emerge as signals of improvement.

In the first big idea, the participant noted using demonstrations as a teaching strategy. As indicated by the following statements:

> [S]ee, *[sic]* most of the cases it is advisable to have a model. You have a sample, you put a sample here, either a picture or the motor itself. Okay. If you have either of the two where your model *[sic],* let's say you have a model that is cut to show the inner parts of the motor.

Excerpt 4.26: The usage of demonstration as a teaching strategy

The participant thoroughly explained how to use the teaching strategy and further supported it by using appropriate teaching media.

The participant offered questions that did not require higher-order thinking abilities from the learners for the second prompt (D2) in the first big idea. Only one question from the master CoRe was asked. The participant noted *"In most of the cases, I would give them, let's say, the model itself or a picture of the model itself. And then I would say the name, all the parts that you see."* This question focused only on learners who recalled their previous year's work.

In the second big idea, the participant focused on demonstration as the leading teaching strategy with the help of visual aids as a bar magnet. As indicated in the following statements:

[U]h, in most of the cases, if you have the bar magnet, and then having the iron filings, and then sprinkling them on top of the paper when you have the bar magnet under the paper, that they can see that there's a field, there's a field around the bar magnet. So that, that helps, that it helps much because they can see as long as they understand that there's a field, as soon as current stat moving, even in a conductor, then this field is created around the, the conductor, then it becomes better.

Excerpt 4.27: The use of demonstration and visual aids

The participant used more than one teaching method to improve the lesson's effectiveness.

The second big idea's second prompt does not clearly show the understanding of conceptual progression ordering. The participant only asked one question, which focused on the learners' lower conceptual development. *"Number one, what is holding the road not to touch the windings of the stator?"* the participant said. *"Then name or give the law of magnetism."* Magnetism laws were taught in grade 10, thus they should be considered as lower-order questions for Grade 12 learners.

For the last big idea, the participant described more of teaching media than teaching strategies. The participant mentioned the following:

[I]'ll be having a laptop. I'll be having, uh, a smart board. I'll be having a meter. They should know and see. Remember, we are using a megger here, *[sic]* insulation resistance tester. They should see the difference between *[sic]* insulation tester and a multimeter. Because you're not to use a multimeter to, uh, test for insulation resistance. Because, uh, a multimeter doesn't have all those capabilities of calculating for insulation resistance. So those are the things that I basically *[sic]* use.

Excerpt 4.28: Description of teaching strategies by Participant 3

In the paragraph above, there is no mention of a teaching strategy. Only the teaching media used were mentioned. This means that the participant is unaware of teaching strategies or forgot to mention them. The response is not connected to the question asked.

Under questions that the participant normally asks during the teaching strategy, it was noted that the participant has a sound knowledge of questions to ask the learners during the lesson. All the questions presented were of the highest order, required critical thinking skills, and would lead learners to the constructive development of concepts. The participant mentioned:

[N]umber one, I would say if you're testing for insulation resistance, what scale should you choose on the meter? Okay. If you're, if you are testing for *[sic]*, for continuity, what scale would you choose on the meter? And then what type of, uh, meter are you going to use when you want to test for insulation resistance on a three-phase motor?

Excerpt 4.29: Questions asked during a lesson

There is clear knowledge of scaffolding from the above extract. The participant is using learners' prior knowledge to bring them to a new understanding using these questions. These questions normally led to the development of appropriate assessment activities as seen in the last interview question. The participant is noted repeating some of these questions when responding to the assessment question.

Representations and analogies

The representations chosen by the participant are adequate for construction. There is some indication that visualisations were used to help with the growth of concepts. As mentioned below:

[T]eaching media in most of the *[sic]* cases, you must have, let's say, a laptop. Okay. And you must be having either, if you don't have a smart board as in, what do they call them? You have a small TV in front of them. You must have, what do you call it again? The overhead project, all right, projector. And these learners can see what you're talking about.

Excerpt 4.30: Selection of teaching media for the lesson

The use of teaching media to make learning interesting and exciting is a good standard practice. Further, it was explained that *"the TV either you can connect it to a laptop or you can use the USB. Where you have your notes, your pictures of the motor from the USB."*

In the second big idea, the participant made considerable use of visualisations to reinforce certain parts of the principles being explored. In the statement below:

Okay. In most of the cases, YouTube helps. Okay. Because, uh, to be having those pictures, you know, uh, where they try to show the, the movement of, uh, the magnetic field. Okay. Between, between the, uh, the rotor and the stator, opposing one another so that, uh, there can be that force pushing the rotor so that it starts moving.

Excerpt 4.31: The use of representations to improve quality teaching and learning

The participant described how the chosen representations were employed, which corresponded to the facts in the Master CoRe.

There is some evidence of the use of visualisations to help the theoretical advancement of the final big idea. The participant does not supply all of the master CoRe representations. As already indicated *"I would use a laptop. I would use a smart board. I would use, I would use insulation resistance tester. Which is called megger."* The participant used an insulation resistance tester to perform the two electrical inspections prescribed by the PAT.

Additional Questions not linked to a specific component.

To fully understand the participant's pPCK for three-phase induction motors, I needed to also view how the participant assesses learning. This question sought to analyse how Participant 2 utilises assessment as a tool for improving the educational process.

In the first big idea, the participant presented the assessment to be given to the learners without explaining the type of assessment. As noted below:

> [U]h, number one, uh, you can say name all the parts of *[sic]* of the motor. Number two, give them different types of motors that shows *[sic]* the windings, and ask which one is either DC *[sic]* or AC machine or three-phase machine. And then you can have different types of the *[sic]* rotors where one rotor can have a commutator and the other doesn't have a commutator. And then you ask which one is the rotor for a single-phase machine. And then you can have different sizes of the rotors. And ask which one here is for a three-phase.

Excerpt 4.32: Learning assessment for the construction of a three-phase motor

The participant simply explained the questions to be used after teaching the learners about the construction of a three-phase motor. The assessment above shows the participant's understanding of assessment as it assists in the monitoring of learner growth, direction of instructional decisions, enhancement of motivation, and assurance of educational responsibility.

In the second big idea, the participant gave a more coherent response on assessment. First, the participant explained the purpose of the assessment, as noted below:

[U]h, you know, if, if they can understand the, uh, the construction of, uh, uh, the windings of both the stator and the rotor, and then understand the effects of the movement of magnetism between both, both the stator and the rotor. Uh, how do they affect each other? How do they push each other to rotate? Then I think I better understand will *[sic]* occur.

Excerpt 4.33: Assessment of the Operational Principle

Second, the participant provided an assessment to be used for the big idea. As indicated *"Class activities, yes, in most of the cases, in the form of question papers, in the form of mini-tests."* This demonstrates the participant's ability to effectively assess learners on the principle of operation. Another important feature of assessments is their role in directing teachers' instructional decisions.

Under the testing of a three-phase motor, the participant also showed an understanding of the assessment needed to assist in monitoring the progress of learners. The participant noted *"Number one, uh, give them class activities. Uh, give them homework, uh, test at the end."* This information is sufficient to assess learners as the activities are a mix of formal and informal assessments. Examiners often use the same activities to formulate summative tasks at the end of an academic year. This technique aids in the continual improvement of the educational system by allowing teachers to discover areas where students may require more help or difficulties, allowing them to adjust their teaching methods to match the requirements of individual students.

4.4.2. Observation 2

Participant 2 presented the class in the workshop, which was outfitted with cutting-edge electrical equipment. The course comprised interactive learning areas that simulated power system configurations and projects completed by previous learners. Using these facilities, learners can model and experiment with electrical circuits, transformers, motors, outdated electrical equipment and protective systems. The interactive nature of these learning environments encourages learners to apply theoretical information to practical situations.

The use of teaching media was evident in the construction of a three-phase motor, and all the media expressed during the interview were used. The selected teaching method is a learner-centred method, where the teacher encourages learners to help each other in challenging situations and assists them only when needed. This enables learners to take responsibility for their education. The learner-centred teaching strategy was used throughout the three big ideas. This teaching strategy was not discussed during the interview. The participant asked questions about identifying the difference between a single-phase motor and a three-phase motor. However, these questions were not discussed in the interview. The participant displayed the parts of a three-phase motor and their functions on the board. Learners could read, and it was helpful to them for identification of the parts and their functions. The identification of the motor parts was regarded as important by the participants during the interview. The applications of a three-phase induction motor were also discussed, although they were not part of the interview. Finally, the participant addressed the benefits of a three-phase motor over a single-phase motor. This concept was discussed in the interview. The learners' misconceptions were properly handled as motors were displayed.

Regarding the principle of operation, the participant did not use the iron filings as discussed in the interview. The teaching medium used is similar to that used in the construction of a three-phase motor. the participant made the lesson more learner-centred by asking them to read notes. The laws of magnetism were discussed, along with the cause of the rotor's rotation. the concepts discussed during the observation were part of the participant's interview discussion. Other concepts were discussed during the observation but were not part of the interview discussions. Concepts such as slip, synchronous speed, rotor speed, efficiency, and losses The representations mentioned under the principle of operation of a three-phase motor were not all used as discussed in the interview. YouTube videos were not used to help explain the construction or the operation principle of the three-phase motor. The participant did not ensure that learners no longer had the misconceptions discussed in the interview. The emphasis on the rotor not being connected directly to the supply was not made, thus learners may still have the same misconception.

For the testing of a three-phase motor, the teaching media used were consistent with what was discussed in the interview. The participant used a learner-centred method to explain the tests to be performed and asked questions to keep the learners included. The usage of the test tools and the motor was ignored as they were only on display. The questions asked during the lesson were consistent with those found in the interview. The concept of commissioning was part of the lesson, even though it was never discussed during the interview. The assessment discussed during the interview was not given to the learners.

4.4.3. Summary of Participant 2's PCK (Case 2)

The second participant's pPCK was well described through the interviews. His knowledge of the curriculum, teaching strategies, learning needs and context were apparent for all three big ideas. Although certain aspects were not fully discussed. Aspects like teaching strategies used for lessons, the participant may have misinterpreted the question and explained teaching media. The explanation of the teaching strategy was not aligned with the master CoRe as the participant selected a single teaching strategy for each big idea. The selection of a single teaching strategy for a lesson suggests that the teacher will not cater for the diverse learning styles of a regular classroom. The questions asked by the participant did not require higher-order thinking or provoke critical thinking from the learners. Thus, compared to the master CoRe, the participant still has room for improvement.

The observation gave a clear description of the participant's ePCK. The lesson design, presentation, usage of educational media, and teaching techniques were observed. The participant used a learner-centred method that improved the pace of the lesson as it made it reduced the number of questions asked by the learners during the lesson. With the improved pace of the lesson, not all objectives were met. The testing of a three-phase motor was not fully presented. The participant did not demonstrate the tests to the learners.

The participant could present most of the topics discussed during the interview. That gives us an indication of alignment between the teacher's pPCK and ePCK. However, certain aspects did not align together, namely the teaching strategies, questions asked and assessment. A different teaching strategy was used during the lesson observation as compared to what was discussed during the interview. This change in teaching strategies may have affected the questions asked during the lesson. Thus, when comparing the teacher's pPCK with the ePCK we can see several differences.

4.5. CASE 3 – PARTICIPANT 3

Table 4.3 below, represents the summary of participant 3 scores from the interview and observation. The participant's scores are compared to the master CoRes and then used to determine whether the participant has sufficient or insufficient PCK.

***Table 4.3**: Participant 3 interview and observation compared to the master CoRe.*

	Interview				Observation			
Component prompts	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Knowledge and skills related to curricular saliency		**X**			**X**			
Knowledge and skills related to conceptual teaching strategies		**X**				**X**		
Knowledge and skills related to students' understanding of technology		**X**				**X**		
Representations			**X**			**X**		
Questions not related to a certain component		**X**			**X**			

The "X's" in the table represent the scores attached to a specific PCK component based on the interview and observation discussions from Participant 3.

4.5.1. Interview 3

Curricular saliency

One of the most essential aspects of curricular saliency is its influence on learners' involvement. A curriculum intended to ignite curiosity among learners and motivate them to be engaged in their education is more likely to succeed. According to Hidi and Renninger (2006), When learners believe the curriculum is relevant to their lives, they are prone to become intensely engaged in their education. This involvement can lead to increased intrinsic motivation and a sense of ownership over their education.

Under the construction of a three-phase motor, for the first prompt (A1), participant 3 gave one appropriate response to this prompt (see Appendix B). Other discussed responses are mainly for the second big idea. The participant explained:

[A]ccording to me, we need to understand, *[sic]* conceptualise the topic on its own first, conceptualise the topic. And then while you are conceptualising, you will remind them of the topic based on magnetism, as point number one, and then from there is then maybe we can start to dwell in with *[sic]* the construction of the motor. Because as we know, that *[sic]* we've got different types of these motors, we've got the spooling cage based on induction. That is when now we emphasise based on induction.

Excerpt 4.34: What students are intended to learn

Only the types of motors appear in the master CoRe. The other responses were mainly related to the principle of operation.

For the second prompt (A2), the participant explained the prior knowledge that learners need to understand the construction. This is an inappropriate response as the question is based on the purpose of the construction and not the learners' past education. As indicated *"Basically, according to this experiment from Professor Oersted, when they say current carrying conductor, magnetic fields have been created."* This analogy of the current-carrying conductor is relevant to the next big idea regarding the principle of operation.

For the third prompt (A3) under construction, the participant demonstrated some understanding of the learners' prior knowledge that is needed. Noting that *"they must start from the known to the unknown"* and then proceed to explain concepts of interest. The participant went on to state:

[M]aybe a plane, you take it from just an ordinary motor, yeah, we need to understand what type of motor is this. Let's say, for an *[sic]* example, just take a pure DC motor and explain what is happening inside. Just a simple motor, maybe a toy motor whereby we've got a magnet inside and we've got a coil that is running between the magnetics right now, we tend to explain that now, when we go to bigger motors, we are going to create these magnets, but in smaller motors, we've got those permanent magnets that will try to make the rotor to rotate or the armature to rotate.

Excerpt 4.35: Scaffolding by Participant 3

The sole concept recognised as important to the construction of a three-phase motor is concerning the parts of a motor, which pertain to rudimentary concepts typically regarded as fundamental to the issue. Other relevant ideas were left out.

For the last prompt under the construction, the participant noted that *"Nothing to hide, learners much more everything, pertaining to the construction of a motor."* Regarding the master CoRe, certain concepts may be taught at a later stage once learners understand the fundamentals of the construction of a three-phase motor.

In the second big idea (the principle of operation), for the first prompt (A1) the participant noted two responses to the question that were appropriate. Other subtopics are missing. Based on the statement below:

> [F]irst of all, they must know the motor in itself is too inductive. They know the principle, why do we say induction motor? First of all, they will be able to define it. So that simply means this induction motor you can link it with the operation of a transform. You know that in this motor there are no physical connection *[sic].* Only does apply and it is a brushless motor. That is not the material in operation. Now what is happening inside, hence I'm trying to link it with the operation of a transform. So that *[sic]* basically, they must know. So there's no physical connection between the rotor and the field windings

Excerpt 4.36: What learners need to be taught about the operational principle

The appropriate responses are only about the inductive nature of the motor and the linkage of the operation of a three-phase motor to that of a transformer.

For the second prompt (A2), the participant gave responses that were meant for the general goal of education and not specific to the operation of a three-phase motor. The participant explained:

> [T]hey need to know the basic operation. How does that thing operates *[sic]* basically? Because you cannot just learn a thing and yet at the end of the day you cannot explain what is happening inside. So that *[sic]* you need to know how does *[sic]* it operates. Hence now, as I've already mentioned, they need to understand that this is the thing. It is too inductive. Hence, it is basically the operation. It is basically based on the operation of a transformer. So they need to know the operation. You cannot just drive a car and yet you buy a car and yet you cannot drive it.

Excerpt 4.37: Goals of the Operational Principle

The participant later added more general goals related to education.

For the third prompt (A3), the participant stated concepts that are relevant to the first big idea. It was noted that *"They must know different parts of the motor. And the behaviour of those parts of the motor,* *how do they behave? And because it's a three-phase motor, we need to explain why is it a three-phase motor."* The response shows a lack of curricular saliency from the participant and some need for development.

For the last prompt (A4), the participant noted *"I mean, since you have told them about the principle of operation, I mean, why hiding [sic] some of the information?"* This comment demonstrates little awareness of scaffolding and the inconsistent placement of ideas.

In the third big idea (the testing of a three-phase motor), for the first prompt (A1), the participant provided responses based on the background knowledge for learners to understand how to test. This information was not necessary for the question asked. As seen in the statement below:

> I can say before you can say they must test a motor, they need to have a theoretical background first. Theoretical background in a sense of information on how to conduct those tests. Thereafter is then now what they have discovered from theory, they are going to do it in application. And they must get it according to what the book says. When testing the movie. Because I've got one printout here that explains exactly what they must do before they can do the testing of motors and so forth. You tell them step by step what they must do. Then from that, that is what I'm expecting when they go there. Because we know that if they can *[sic]* miss one of the tests with the motor and it's not carried accordingly. We know we have got a problem.

Excerpt 4.38: Theoretical background about testing a motor

The extract presents a discussion relevant to prompt A3. A3 is based on learners' prior knowledge of testing a three-phase motor. The participant later gave more appropriate responses. As noted, *"the testing of windings as an example. Testing of earth. Testing of earth to windings."* These tests represent the three electrical inspections as noted in the master CoRe.

For the second prompt (A2), the participant gave only one response relating to those found in the master CoRe. It was noted *"It's for protection. It's for protection. And to apply the knowledge as the book says."* the participant did not discuss other objectives of testing a three-phase motor. The response fell short of what was expected, showing a deficiency in his pPCK and it may ultimately affect the ePCK of the participant.

In prompt A3 (see Appendix B), the discussion was based on the concepts outlined in the master CoRe. The participant noted the functions of the tests to be performed first. As outlined below:

[D]ifferent types of instruments. You know the function of each instrument. Where do we use it? How do we use it? So that they must be able to know which instrument is used where. How to use it. Let's say maybe for an *[sic]* example, you bring them with a tongue tester. they must know how to use it.

Excerpt 4.39: Preconcepts needed before learning about testing a three-phase motor

The participant added *"Megger. Use a megger"* [to perform the tests on a three-phase motor].

For the last prompt on the testing of a three-phase motor, the participant noted *"I don't have any. All what [sic] we are doing is according to the book."* Meaning learners must be taught everything about testing a three-phase motor at this stage.

What makes a topic easy or difficult to understand?

In this section, my investigation reveals the principles that form educational knowledge as I navigate the cognitive environments of learning.

The difficulty in teaching the construction of a three-phase motor was attributed to learners' attitudes towards the subject. The participant stated:

[B]ecause our learners, they *[sic]* are not that much dynamic because there are some instances, they don't take things seriously, but if you teach them with a thing that they can see and it must be operational, that is one thing that you need to have for them to be able to understand some of the things you need to have your teaching aids and be able to interpret whatever that you see in the teaching aids or explain it, try to dismantle it and explain it to each and every component that is the function of the component and how does it aid if you apply the source of supply to it.

Excerpt 4.40: Difficulties in teaching the construction

Aids to improve learners' interests are also provided in the extract above. The participant did not mention content difficulties that affected learners' understanding. This may indicate a deficiency in the pPCK of the participant.

The difficulties in teaching the operation of a three-phase motor were attributed to language usage. As one of the master CoRe prompts are based on terminologies, the participant provided one of the challenges faced by most teachers. Evidenced below:

[I]n this instance, kids are not able to interpret the technical language. And it is difficult for them sometimes to express themselves, technically so. And in some instances, they are not exposed to these things. They only see them here.

Excerpt 4.41: Difficulties in teaching the operational principle

It is clear that there is some knowledge about academic difficulties, yet not enough as some concepts are overlooked.

Difficulties found in teaching the testing of a three-phase motor emanated from disregarding safety. As the participant explains below:

[O]ur kids don't take safety serious *[sic].* Especially when using the megger. They don't take it serious *[sic].* Because I had an incident one time, I gave them instructions. You must do this, test it. Then the other one had to shock a learner with the megger. Hence now I say safety, it's priority number one. Especially when using Whatever the *[sic]* instrument that you are using.

Excerpt 4.42: Difficulties in teaching testing of a three-phase motor

From the master CoRe, the only noted difficulty is interpreting the results from the tests performed by the learners.

Learner Prior Knowledge

Learners already have a plethora of information and experiences before the first class even begins. These foundations impact their learning and form their perspectives, laying the framework for new insights. In this section, I will be focusing on how the participant includes learners' prior knowledge in the lesson.

Regarding the construction of three-phase motors, the participant did not discuss any misconceptions about the topic. It was noted, *"They think if you teach them about this motor, it's just for leisure, not knowing where do we operate, where do we use them in operational situations, yeah, because one might ask you, why do we have to learn motors, but we say we are doing electrical, that's what I'm trying to say."* the above response from the participant indicates an incorrect interpretation of prompt B1 (see Appendix B).

The misconceptions indicated under the principle of operation were described exceptionally, as indicated in the master CoRe. The participant indicated:

[I]n that case, what frustrates them, especially when you explain that this thing, it is too inductive. Because there's no physical connection. Because they want to see a connection. Because *[sic]* as you see, current carrying conductor and there is a magnetic field, but now in this one, they become confused and frustrated. What makes the rotor to *[sic]* rotate because there's no connection? As we know from the previous motors that *[sic]* we do have brushes and there is a current flowing through the brushes by the commutators and all the windings that form the amateur to rotate. But now in this one, it becomes now, they become sceptical now *[sic].* What is the cause? What makes it to *[sic]* rotate? But there's no connection. We only supply the field windings, but there's a rotation. But then, that's what makes them to be sceptical about this.

Excerpt 4.43: Misconceptions about the operational principle

The participant indicated knowledge and understanding of misconceptions.

For the last big idea (testing a three-phase motor), the participant displayed a deficiency of knowledge of misconceptions. As stated below:

[T]hey just think maybe testing you are just doing it for the sake of doing it. As if now there's no purpose for doing testing. That is what's just in their mind. Why do we test? This thing is from the factory. Sometimes this thing can have factory faults. You cannot just take it and fit it in, you must test it before.

Excerpt 4.44: Misconceptions about testing a three-phase motor

The participant's response is inadequately phrased and does not demonstrate an inaccurate view or opinion because of flawed thinking or comprehension by the learners.

Conceptual Teaching Strategies

In this section, I'll focus on the teaching tactics utilised by the participant to improve his interactions with the learners.

Under construction, the participant noted the best teaching strategies to use are *"the teaching strategy that is best is demonstration and narrative."* The participant's strategies are workable as the usage of multiple teaching strategies relates to curriculum saliency. One of the primary benefits of using several teaching methods is their capacity to accommodate different learning styles.

The questions that the participant normally asks in the teaching strategies are of good quality, as they are directly linked to the master CoRe. As noted below:

[Y]ou can ask them about the operation. To be able to pinpoint different parts and know how to explain them. How to find the information of the motor (nameplate). And they must know the purpose or the function of a motor.

Excerpt 4.45: Questions asked by Participant 3 when teaching the construction

Besides the operation of a motor being asked this early, the rest of the questions are perfect, as they evoke critical thinking skills from the learners and form a base for assessment.

For the second big idea (principle of operation), the strategy recommended by the participant is not sufficient for helping learners understand the topic. A description of how the strategy will be used was given as noted below:

[T]he strategies that I use, I just start it from grade 10, just *[sic]* to recall. As a revision, trying to explain *[sic]* electromagnet, and the inductor as an electromagnet, putting the iron core for strengthening of *[sic]* magnetic field. You bring that to your back, then you put it into *[sic]* application. So that they must see that magnetism is very important.

Excerpt 4.46: Recommended teaching strategy for operational principle

After the explanation the participant named the strategy to be used, *"It's a narrative method"* It becomes challenging to encourage the development of multiple learning styles when a single teaching strategy is used.

The questions recommended by the participant in this teaching strategy show no evidence of support for conceptual understanding. As noted, *"You must consider the effect of why and how. And what is happening? Actually, we are able to explain why. That is the how part and the why part."* The participant did not show any understanding of the questions needed to support the teaching strategy for effective learning.

Under the last big idea (testing a three-phase motor), the participant noted a single teaching strategy. The response was *"Demonstration. Must first demonstrate. Put more emphasis on the do's and the don'ts."* This shows that the participant lacks an understanding of teaching methods and their influence on performance.

The questions normally asked by the participant are sufficient and will provoke critical thinking skills from the learners. The participant asked questions such as, *"How and why? Why do we do tests? And how do we carry out tests? And they must explain what is the importance."* These questions are consistent with the master CoRe owing to their cohesive nature.

Representations and analogies

For this section, I focus on the teaching media and representations used in the classroom for the lesson. These representations will aid the lesson and make it interactive and exciting.

For the construction of a three-phase motor, the participant is noted using *"now as we do have physical motors, As a media, sometimes we do have these videos from YouTube as a reference because those ones we use them as visual aids in any way so that they might see what is happening."* The participant shows dexterity in using representations to develop learners' understanding of the topic.

Under the operational principle, the representations were of a good standard. The participant said *"You have, uh, overhead project. Using the PC. For now so far, and the panels that we are having. For demonstration purposes, especially when we connect."* These representations are consistent with the master CoRe.

In the testing of a three-phase motor, the representations provided show exceptional knowledge of teaching media selection. Noted in the statement below:

[W]e are using physical equipment now. Physical equipment. We do have a motor which is standing right for them. Not connected on *[sic]* the source. And then. And various types of instruments that you would be multimeter in the megger too.

Excerpt 4.47: Selection of teaching media

The extract shows a perfect understanding of the media needed to ensure that learners understand how to test a three-phase motor.

Additional Questions not linked to a specific component.

The participant has good quality knowledge related to assessment. He uses a learner-centred approach, enabling learners to take responsibility for their education. As evidenced below:

> [I]t can be the first one, I prefer self-assessment. Then peer assessment. Then after that is then *[sic]* I can start to give them an official test where I'm going to assess them on my own. That is teacher assessment. But preferably I like it as peer assessment because that is where they are able to discuss some other points.

Excerpt 4.48: Learner-centred assessment

These forms of formative assessments are consistent with the master CoRe. Black and Wiliam (1998) emphasise the significance of formative assessment in enhancing learning outcomes. It enables teachers to discover areas where learners may require more assistance or difficulties, allowing them to adjust their teaching approaches to match the requirements of individual learners.

Regarding the principle of operation, the participant did not give enough responses to suggest good knowledge of assessment. The response captured is *"Basically, you simply phrase the question, theoretically so. Then they explain it. Doing the writing. Because sometimes even if you can just ask them verbally so, they can just explain, but they are going to miss some other points."* The response may represent a deficiency of assessment knowledge regarding the operation of a motor. This deficiency may lead to learners failing to answer higher-order questions during summative assessments.

For the last big idea, the forms of assessment recommended by the participant are based on the practical work as it is noted that *"You do assess them. I must do it one by one. That is individual."* Individualised assessments are mainly designed for practical work. This assessment shows disregard for the theoretical work covered during the lesson and is thus insufficient to ensure learners' progress.

4.5.2. Observation 3

For Participant 3, the lesson took place in the electrical technology workshop. The workshop consists of the latest test equipment, transformers, motor panels, and learner projects. Posters and charts are displayed, and the floor has markings for demarcated areas. It has the atmosphere of an industrial site, making it perfect for teaching learners real-life scenarios. The workshop is mostly used by electrical technology learners from grades 10 to 12. The learners were quiet and ready to learn.

The teaching strategy used by the participant was the narrative method for all the big ideas. The participant specified two teaching styles, namely narrative and illustration, but employed just one method for all three topics. As indicated by the master CoRe, a single strategy is not sufficient to successfully teach all the big ideas. Most of the media selected by the participants were not in use. The participant did not use the motor displayed in the video to help the learners identify the parts. The topic was not indicated to the learners on the board. Only an overview of the whole chapter was given. The misconceptions expressed by the teacher in the interviews were neither exposed nor eliminated.

For the construction of a three-phase motor, the participant asked questions that were not discussed during the interview. However, the questions pushed learners to think about the construction of a three-phase motor. The participant helped learners recall their previous knowledge by asking questions regarding the previous chapter to provide scaffolding. The participant included an explanation of motor starters; this was not part of the three big ideas, nor was it discussed during the interview. The participant explained induction, as discussed in the interviews. The learners were asked questions regarding induction to increase their interest in the chapter. The participant also mentioned the type of motor to be taught, as there are many types of motors. The participant explained the identification of the parts of a three-phase motor and their functions, even though they were not discussed in the interview. Some questions indicated in the interviews were not asked.

Regarding the operational principle, the participant explained to the learners the generation of a three-phase waveform, even though it was not discussed under the learners' prior knowledge during the interview. The participant did not help learners with language usage, as he mentioned in the interview, as it is one of their challenges. The participant kept using the vernacular in some parts of the lesson. The participant explained magnetism again and how the motor operates using the principle of magnetism. As discussed in the interview, the participant explained the relationship between the three-phase motor and the three-phase transformer using the principle of operation. Applications and advantages were also discussed during the lesson, although the participant did not mention them in the interview. The assessment was not given to the learner; a few questions were asked at the end of the lesson, but they were insufficient to ensure learner understanding. the participants did not give learners feedback when they asked questions.

The participant did not give a lesson on the last big idea (testing of a three-phase motor). The test equipment was not used, the learners did not receive any assessment regarding the last big idea, and the demonstration method was not used for this lesson.

4.5.3. Summary of Participant 3's PCK (Case 3)

The third participant provided valuable information for the description of his pPCK via the interview. PPCK, according to Magnusson et al. (1999), permits teachers to make educated decisions about material selection, sequencing, and the deployment of teaching techniques that maximise student learning. The participant discussed the objectives of the curriculum regarding three-phase induction motors, good teaching strategies to use in the classroom, representations, and questions he usually asks. Some of the mentioned aspects were not fully discussed. The participant had challenges with teaching strategies and questions that learners are usually asked. These challenges present a misalignment with the master CoRe and may point to a need for pPCK development.

The enactment of his pPCK was apparent from interviews to classroom observation, although the participant did not give a lesson on the last big idea. The construction and the operational principle were presented and fully discussed. The observation provided a good description of the participant's ePCK, although there were indications of a need for ePCK development in some parts of the lesson as the participant did not provide any form of assessment at the end of the lesson.

A clear comparison between the teacher's pPCK and ePCK can be made through the interview and lesson observation. Certain parts were presented as discussed during the interview and other aspects that were supposed to be part of the lesson went missing. The participant could use learners' prior knowledge to teach what is unknown and he could reach the objectives of the construction and the operational principle. However, the participant did not use the questions discussed during the interviews and the teaching approach used during the lesson was dissimilar to the one discussed in the interviews. This may be caused by under-preparedness. However, the representations discussed during interviews were used in the lesson.

4.6. CASE 4 – PARTICIPANT 4

Table 4.4 below, represents the summary of participant 4 scores from the interview and observation. The participant's scores are compared to the master CoRes and then used to determine whether the participant has sufficient or insufficient PCK.

***Table 4.4**: Participant 4 interview and observation compared to the master CoRe.*

	Interview				Observation			
Component prompts	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Knowledge and skills related to curricular saliency		**X**					**X**	
Knowledge and skills related to conceptual teaching strategies			**X**				**X**	
Knowledge and skills related to students' understanding of technology		**X**				**X**		
Representations			**X**				**X**	
Questions not related to a certain component			**X**		**X**			

The "X's" in the table represent the scores attached to a specific PCK component based on the interview and observation discussions from Participant 4.

4.6.1. Interview 4

The fourth participant opted to give his own 3 big ideas that he used for preparing and teaching three-phase induction motors. The big ideas are the construction of a motor, the types of motors, and the supply to different motors. Below is the transcription organised according to the big ideas.

Curricular saliency

In this section, I focused on the participant's knowledge of the curriculum and how he adapts it to better suit the learners' needs.

For the construction of a three-phase motor, in the first prompt (A1) the participant exhibited some understanding of the concepts important for learners' development. As discussed below:

[A]s these learners are coming from grade 11 what they know is only a single-phase motor. And with a single-phase motor, they do know that it has got some other parts which are called like *[sic]* capacitors for instance. Now introducing them to a three-phase motor they must know that with a three-phase motor, we no longer have capacitors in a three-phase motor because a three-phase motor is self-starting. It does not need any other assistance like a single-phase motor. A three-phase motor has got *[sic]* different parts as compared to a single-phase motor but of course, some of the parts will be similar and then I will be showing them all the different parts that are available in a three-phase motor and then what they should know in that particular motor is how those parts are interacting with each other to make that motor to be complete in terms of the operation.

Excerpt 4.49: Concepts to be taught for the construction of a three-phase motor

In the above extract, the participant displays some understanding of the intended objectives of the construction of a three-phase motor. By stating the parts of a three-phase motor and linking them to the single-phase motor, the participant mirrors some objectives in the master CoRe.

In the second prompt (A2), the participant showed skilful knowledge in identifying the objectives of the construction of a three-phase motor. In the below statement:

[W]ell, we are building learners who must be skilful because those learners need to know as they are going out to industry that in a motor we have so many parts of the side of the parts and if one of those parts is not working according to the requirement or according to expectations then they should know what that particular thing is, the name of the part and what its purpose is exactly in that particular motor so that fault finding should become easy for them in terms of locating where the fault is or if an error arises.

Excerpt 4.50: The objectives of the construction of a three-phase motor

the participant's goals for teaching learners the construction of three-phase motors are aligned with the master CoRe.

In the third prompt (A3), there is some evidence of knowledge about the content needed to be taught before teaching learners about the construction of a three-phase motor. The participant noted *"The concepts that have to be taught before construction? It is actually the purpose why we should use motors, the application actually. Why is there a need of [sic] motors? I think that is what is important there."* This response demonstrates the participant's lack of scaffolding knowledge, as there is more that can be valuable from earlier grades.

For the last prompt under the construction of a three-phase motor, the participant showed some knowledge regarding what learners do not need to know at this point. It was noted, *"What I don't want learners to know at the beginning is the actual interaction with regard to magnetism because it is a bit confusing and it is imaginary so if you talk about an imaginary thing learners will just look at it like that and they will fail to really get what they are saying exactly."* Magnetism is a concept that should be discussed under the principle of operation of a three-phase motor, the participant did not fully understand the question.

What makes a topic easy or difficult to understand?

I concentrated on the learning landscape in this section, investigating the factors that indicate ease or difficulty in grasping educational concepts according to Participant 4.

The participant's perception of what makes the material challenging to comprehend is based on magnetism. This is not relevant when discussing the construction of a three-phase motor. As noted below:

> [S]o, showing them *[the learners]* the parts is the easiest thing and the difficult thing is now how those parts interact in creating the torque that is caused by the magnetic field. *[sic]* Reason is as I gave before then *[sic],* It is imaginary so that is very difficult. Even if you use videos it will still not sink well.

Excerpt 4.51: Construction difficulties

This argument is relevant when discussing the principle of operation of a three-phase motor thus, it is not in line with the discussions in the master CoRe.

Learner Prior Knowledge

In this section, I focused on the participant's use of prior knowledge to bring learners to a new understanding.

The misconception discussed relates to the principle of operation and not the construction of a three-phase motor. In the statement below:

[Y]eah the misconception is that especially when coming to the effect of current, what current can do, is they think we are just talking. There is something that should be driving the motor except for the power so that is what they mostly argue with me about until it is until it is *[sic]* proven until we connect the motor to to a supply.

Excerpt 4.52: Learning Misconceptions

The participant clearly described a misconception that is suitable to the operational principle.

Conceptual Teaching Strategies

Regarding teaching strategies, the participant described a visual teaching strategy and direct instruction. As evidenced below:

[T]he teaching strategies that I use is it is *[sic]* a practical one, a visual one whereby the parts will be shown as visually on the screen and then thereafter a motor is taken and it is *[sic]* dismantled and the parts are also shown to the learners. Let them have a feeling of those parts, touch them and that is what I want to do.

Excerpt 4.53: Teaching strategies

The selected teaching strategies are relevant for aiding learners in understanding the construction and development of learning styles.

The participant noted many relevant questions regarding the teaching strategy. The questions stated are *"I would normally ask learners the major parts of a motor and then which they will answer me which is the stator, the rotor and the frame and those parts they never forget them."* These questions are insufficient for fostering critical thinking under this big idea. The master CoRe was ignored during the participant's conversations.

Representations and analogies

This segment emphasised the use of educational material and representations to make the lesson more entertaining and engaging.

For the construction, the participant displayed a great understanding of the representations required to assist with learner understanding. As discussed below:

[I] do use YouTube and I also use. I go to the websites where we can find any information about motors and induction motors together with the application just for about 10 minutes so that we see that these are real things that are used in the real world.

Excerpt 4.54: The use of representations and analogies

Videos are common representations that are readily available to most teachers. The DoBE supplies videos and real motors each year to most schools in Gauteng. The discussions by the participants are aligned with the master CoRe.

Additional Questions not linked to a specific component.

Assessment is very important for increasing high school learners' motivation and involvement. Learners are more inclined to put effort into their studies when they have clear goals and expectations of success. Rubrics, self-assessments, and peer evaluations are tools that not only assist learners in grasping what is expected of them but also enhance metacognition and self-regulation abilities, as Sadler (1989) emphasised. These abilities are required for deeper learning and the long-term retention of information. As noted by the participant:

[N]ormally use, I start with long questions. Long questions I refer to things like "Name the parts of your motor." It's a big longer. Some will name three, some will name five and then I will also use multiple choice questions and *[sic]* I will have class tests, weekly class tests on a part on *[sic]* the topic, and I will tell them the questions that I will be asking so that they prepare for those questions and if they fail then it is because they did not read. then that is where you now know that they did not read. I don't hide the questions that I will be asking them in the class test or the weekly test. It is just to make sure that they are ready to prepare.

Excerpt 4.55: Assessment task for learners

The participant simply described the task to be given to the learners. The description is aligned with the master CoRe.

The participant's other two big ideas were not covered since they do not align with the aims of the research. This made them challenging to discuss and compare to the master CoRe and impossible to measure with the discussed rubric (Appendix C).

4.6.2. Observation 4

Participant 4 presented a lesson in a normal classroom. The learners' desks were all facing the chalkboard. The participant's laptop and projector were the only electrical equipment in the classroom. The classroom did not contain any posters or charts relating to electrical technology. The learners were attentive and looked ready to learn. The main topic was displayed using the projector screen. The objectives of the lesson were given to the learners verbally. The only teaching strategy used was the narrative method, not the practical one as explained in the interview.

For the construction of a three-phase induction motor, the representations discussed in the interview were all used as expected during the lesson. First, the participant displayed a cross-section of a three-phase motor while reminding learners of their single-phase motors. The participant discussed the parts of a three-phase motor, as expected from the interviews. The participant also explained the type of motor that learners must focus on, even though the types of motors were given as a big idea at the start of the interview. The explanation of the origin of the term "squirrel cage" is incorrect. The advantages of a three-phase motor were also discussed during the lesson, but not in the interview. A YouTube video was used to further explain other aspects of the construction of a three-phase motor, such as the applications, principle of operation, testing of a three-phase motor, and commissioning.

4.6.3. Summary of Participant 4's PCK (Case 4)

The participant's pPCK was described through the interview. The participant's PCK was only described on a single big idea, as the other two are inconsistent with the study. From the interview, the pPCK of the participant was apparent as the participant provided great curricular knowledge, identified misconceptions, and discussed relevant teaching strategies. For the big idea discussed, the pPCK of the teacher was well described as he displayed knowledge of identifying misconceptions, creating a meaningful learning experience and usage of teaching strategies. The description was aligned with the master CoRe for the construction of a three-phase motor.

The enactment of the PCK described during the interview displayed good curricular knowledge and the teacher's preparedness. The participant displayed a good use of representations, using a PowerPoint presentation and YouTube videos to engage learners. the participant also frequently asked relevant questions and used a combination of teaching strategies (i.e., the question-and-answer method and direct instruction).

The enactment of the participant's PCK was described firmly for the construction of a three-phase motor. during the interview and classroom observation, the participant kept similar strategies, representations and questions asked during the lesson. These similarities may be an indication of the participant's preparedness and exceptional PCK levels. A comparison of the teacher's pPCK and ePCK was drawn for the first big idea only.

4.7. CASE 5 – PARTICIPANT 5

Table 4.5 below, represents the summary of participant 5 scores from the interview and observation. The participant's scores are compared to the master CoRes and then used to determine whether the participant has sufficient or insufficient PCK.

***Table 4.5**: Participant 5 interview and observation compared to the master CoRe.*

	Interview				Observation			
Component prompts	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Knowledge and skills related to curricular saliency			**X**				**X**	
Knowledge and skills related to conceptual teaching strategies		**X**					**X**	
Knowledge and skills related to students' understanding of technology		**X**				**X**		
Representations			**X**				**X**	
Questions not related to a certain component			**X**		**X**			

The "X's" in the table represents the scores attached to a specific PCK component based on the interview and observation discussions from Participant 5.

4.7.1. Interview 5

Curricular saliency

In this section, I focused on the fifth participant's knowledge of the curriculum and how he uses it to improve teaching and learning.

Under the construction of a three-phase motor, in the first prompt (A1), the participant provided a general overview of what learners need to know. The response contained elements found in the master CoRe, but some elements were missing. As noted, *"they [learners] have to know all the purposes of the parts of the motor and how those parts of the motor work and how they operate."* The concepts provided are missing some development to display how they enforce critical thinking in learners regarding the construction of a three-phase motor.

For the second prompt (A2), the participant demonstrated a good understanding of the objectives of the construction of a three-phase motor. In the statement below:

> [U]h it's important because some of the students maybe *[sic]* want to become electrical engineers, so they have to know how those parts operate, how to fix *[sic],* and the effects of the parts on the motor. Like the squirrel cage of the motor, what is its effect on the motor? What happens with the rotor part, and the stator part?

Excerpt 4.56: Objectives of the construction of a three-phase motor

It is clear from the extract that not only are the objectives of the curriculum understood, but also the development of the participant's pPCK.

There is insufficient evidence of scaffolding for the third prompt (A3), and the participant offered goals that are universal to the full programme. As the following suggests:

> [T]he concepts that must be taught to the learners are about the understanding of the motor. The whole parts in the motor how do they function, how does it work before we go deep to the parts of the motor. They must understand the construction and the application.

Excerpt 4.57: Goals regarding three-phase induction motors

The parts of a motor and their functions present a good discussion, however, most of the goals presented are inconsistent with the master CoRe.

For the last prompt, A4, under the construction of a three-phase motor, the participant's response did not show any understanding of the relationship between the construction and assembly of a motor. The participant responded by saying, *"Yes, the assembly of the motor, the connection of the motor inside of the motor inside of the motor."* The construction and assembly are the same. When learners are taught about the parts, they are also taught where those parts are connected.

For the principle of operation of a three-phase motor, in the first prompt (A1), the participant did not give a full description of what the learners needed to know. The participant responded with merely the big ideas. The participant said *"They have to know how does the motor operate. It is important to know how the motor operates and [sic] different types of motors, those with brushes and those without. So they have to know how they operate individually."* The different types of motors are a concept discussed under the construction of a three-phase motor.

In the second prompt (A2), the participant noted *"They have to know that we have different types of motors and each of them operate [sic] differently."* The basic concept is repeated with no additions. The justification given is confined to the general benefit of education.

For prompt A3, the participant gave points that were consistent with the master CoRe and supported them with valid discussions. The participant noted, *"The important things are the parts of the motors because you have to teach learners that in order for the shafts to rotate, what is happening before and what's happening from the supply to the squirrel cage to the rotating part, the stator and the rotor."* The participant argued that the construction discussed before this big idea is of the highest importance. This argument shows the participant's ability to scaffold learning.

For prompt A4, the points presented show knowledge of the curriculum as they are in line with the master CoRe. It was noted, *"how to reduce the magnetic hum on the motor, to increase the rotational speed and how to avoid cogging on a motor."* Some of the concepts are not part of the master CoRe, but they are consistent with what learners do not need to know yet.

For the testing of a three-phase motor, the participant showed good knowledge of the curriculum in the first prompt (A1) by explaining that *"before you use the motor, you need to test if the motor is in a proper state to be used. You cannot use the motor without any testing. You need to test to make sure that the motor is in a good condition to be used."* Although these goals are consistent with the goals of the master CoRe, they are presented in a general form. The participant did not specify the tests that the learners need to perform nor the measuring instruments to be used to perform the tests.

In the second prompt (A2), the participant only mentioned a single aspect that is consistent with the master CoRe, safety. As noted, *"for their own [sic] protection and to protect some of the components on the motor so that it cannot be damaged."* Some elements are missing and as such, the participant is displaying some lack of pPCK regarding this aspect.

In the third prompt (A3), the participant did not fully understand the question and responded by *"They need to know the importance of testing and also they need to know how to test a motor, and they need to know also the dangers that may arise if a motor is not tested."* The only concept consistent with the master CoRe is about the dangers of a motor as it leads to teaching learners about safety.

For the last prompt (A4), the participant is looking to bypass a test that is part of the CAPS document. It was noted, *"the mechanical inspection, like when they need to check inside of the motor as to which components are damaged. The testing of the inside of the motor does not need to be done."* The response is inconsistent with the master CoRe.

What makes a topic easy or difficult to understand?

For this section, I focused on the participant's ability to simplify the topic for the learners.

What the participant discussed about the difficulty in teaching the construction of a three-phase motor is that *"uh what the learners find difficult about the construction is to state the operation of each part of the motor."* The participant focused on the learners' challenges and not the challenges in teaching the concept.

The participant described difficulty in teaching the principle of operation of a three-phase motor as learners' misunderstanding of the control circuits. As noted, *"sometimes the learners have a misunderstanding of the principles of the control circuits."* The participant focused on the wrong topic and did not focus on the challenges of teaching it.

For the testing of a three-phase motor, the participant explained a genuine challenge faced by both the teacher and the learners. in the statement below:

[T]esting insulation resistance between windings. Some of the learners do not understand why we have to do the test, since the wires are already insulated. The learners also do not know what is *[sic]* the maximum value to get when testing for insulation resistance on the motors. They are also struggling with the correct setting for the megger tester, *[sic]* the correct range to select.

Excerpt 4.58: Challenges faced when teaching the construction of a three-phase motor

The described difficulty is compatible with the master CoRe and demonstrates an understanding of teacher problems and their root causes.

Learner Prior Knowledge

Regarding construction, the participant described a misconception that could be found under the principle of operation. The participant said *"The squirrel cage rotor, how does it link to the bearings, how do they work together until the rotor rotates? How does the rotor link to the other parts?"* a lack of knowledge about misconception is noted for the current big idea.

Under the operational principle, the participant noted, *"Most of the time it is the terms we are using on [sic] principle of operation. Those terms are not well understood by the learners."* this is a valid misconception as mentioned in the master CoRe. Learners misuse the terms and thus confuse certain aspects of the operation. The participant did not mention the other misconceptions that learners may have.

The participant perfectly described the misconceptions experienced by the learners under the testing of a three-phase motor. The participant mentioned *"It is the use of equipment because the learners are not sure which tool to use for performing which test. Sometimes the learners use the multimeter to perform the continuity test and the insulation resistance test."* This description is consistent with the one found in the master CoRe. It fully describes the challenges learners are facing.

Conceptual Teaching Strategies

This part focused on teachers' pedagogical methods and how to empower learners with cognitive skills to absorb, question, and synthesise knowledge autonomously, rather than merely facts.

The participants described direct instruction as a teaching strategy for the construction of a three-phase motor. The participant said *"I will break down the questions in order for the kids to understand. Kids must understand the terms, and those terms are broken down so that it can be easy to understand."* The use of a single teaching strategy is insufficient to fully support all the learning styles. This may be an indication of a need for development regarding teaching strategies, as multiple strategies are required for a single lesson according to the master CoRe.

The questions to be asked in the teaching strategy do not show evidence to support conceptual understanding and no sequential development of concepts. Thus, indicating a lack of ePCK. The participant said, *"To label the parts, write down the purpose of the parts."* This question fails to promote the growth of creative thinking abilities and is inconsistent with the master's CoRe.

For the principle of operation of a three-phase motor, the teaching strategy described is insufficient as it focuses on one method of teaching. Direct instruction alone is not sufficient. The participant described the method by saying:

> [S]omething I do is to write them in point form so that it is easy *[sic]* for learners to understand than writing in paragraph form. I put them in point form, like from the supply to the motor, then explain the function of each part in the motor because all the parts have their role in the operation.

Excerpt 4.59: Teaching method for the principle of operation

The strategy was going to become more effective if it was used in conjunction with another as described in the master CoRe.

The questions prepared in the teaching strategy do not support the enhancement of analytical thinking abilities. Although there is evidence of scaffolding, the questions are insufficient to become effective. The participant said:

> Before I go to the principle of operation, I just ask the learners about the functions of those main parts of a motor. Then we can start with the operation once learners remember the functions of the parts. Lastly, we combine everything.

Excerpt 4.60: Strategies used for teaching the operational principle

To test a three-phase induction motor, the selected teaching strategy must contain a more practical approach. As stated, *"I use the demonstration and a video on how they test that motor, then I switch off the video and give them a chance to test the motor without looking at the video."* The demonstration is a good method for teaching about testing and combined with a learner-centred method it helps learners understand better. The response from the participant mirrors those in the master CoRe.

The questions prepared for this teaching strategy are good and they mirror those found in the master CoRe. The participant said *"Which inspections are done on a motor? Under the inspections, learners have to explain how each inspection is performed."* These questions will help learners develop memory recall skills and they will also prepare the learners for any assessment that may come.

Representations and analogies

The representations mentioned for teaching the construction of a three-phase motor are sufficient for supporting the learning process. As also mentioned in the master CoRe, the participant said, *"I'm using PowerPoint to project the parts of the motor separately, use charts as well as the videos."* There is sufficient representational selection and some signs of conceptual improvement.

Regarding the principle of operation, the participant focused on using videos to help explain the operation. This mirrored the notions of the master CoRe. The participant stated that:

[I] use videos from YouTube, they are easy to use and for learners to understand. When we talk about the rotor, the rotating part, I would show them from the video on how the rotor gets to rotate.

Excerpt 4.61: Representations to be used

The participant showed some exemplary knowledge about representations to best select in aiding the learning of the principle of operation.

Under the testing of a three-phase motor, the participant said, *"I use PowerPoint, videos and also charts."* The usage of the test equipment and a three-phase motor were overlooked. This reduces the ability to improve learning.

Additional Questions not linked to a specific component.

The participant showed good knowledge of the assessment of the construction of a three-phase induction motor. A formative assessment as mentioned *"I give them short, controlled tests based on the parts that were done in class and short controlled classwork. Then I mark them so we can do corrections."* Is a good way to check learners' understanding and thus improve their knowledge about the topic.

The assessment of the principle of operation of a three-phase motor is also well structured as it focuses on improving learners' knowledge. The participant said *"I just give them the controlled class works, and I give them time to complete the activity. When the time has elapsed, I collect the papers and we do corrections."* The formative assessment is also useful, as it mirrors the objectives of the master CoRe.

For the testing of a three-phase motor, the assessments mentioned by the participant showed knowledge of the assessment styles and usage of different assessment techniques. The participant said, *"I use different types of question papers from different provinces, and also using questions from different textbooks."* This also prepares learners for the summative assessment.

4.7.2. Observation 5

Participant 5 had the lesson in the electrical technology workshop. The workshop has the latest transformer panels, tools, former learners' projects on display, charts, and motor panels delivered by the DoBE. Some charts were self-created by the participant, as demonstrated by the video. The participant put in too much work to ensure that the workshop atmosphere could simulate realistic scenarios. The participant had the teaching media nearby, but because of load-shedding, he could not use the projector screen. The narrative method was used as the teaching strategy for all topics. The participant also used questions to ensure that the learners were contributing to the lesson.

For the construction of a three-phase motor, the objectives were verbally expressed to the learners, and the learners took turns naming the parts of the motor. The participant discussed the different types of motors, the parts of a squirrel cage induction motor, the purpose of the stator and the rotor in a motor, and the construction of the rotor. The participant mentioned the intention to teach learners about the parts during the interview; this objective was achieved. The participant did not ask all the questions noted in his interview; some questions were relevant to the lesson but were not discussed during the interview. The motor assembly was also discussed during the lesson. The misconception discussed during the interview was not addressed in the lesson.

For the operational principle, only the operation of the squirrel cage induction motor was discussed. The participant gave the learners a chance to individually explain the basic operation of the motor. As discussed in the interview, the participant asked the learners questions regarding the functions of the parts of the motor and then used the explanation to explain the operation of the motor. During this explanation of the operation, losses, advantages, and changing the direction of rotation were also discussed. These concepts were not part of the interview discussions. The misconception regarding learners' language usage was not addressed, as the participant used vernacular in some parts of his lessons.

When testing a three-phase induction motor, the participant did not use the teaching strategies discussed during the interviews; instead, direct instruction was used. As discussed in the interview, the participant explained the tests that should be carried out on the motor, the test equipment that needs to be used, and the protective devices, and demonstrated how the insulation resistance tester is used. The participant's demonstration using the insulation resistance tester was not carried out correctly, and it disregarded the safety of the operator. The misconceptions discussed during the interview were not addressed during the lesson. Charts were not used during the lesson, even though they were part of his teaching strategy. The assessment for all the big ideas was done verbally, so the participants asked learners questions, and they could discuss the topic towards the end of the lesson.

4.7.3. Summary of Participant 5's PCK (Case 5)

All the research questions were answered as the participants responded to all interview questions. The pPCK of the participant was well described in the interviews as all the research questions were answered. The participant shared his knowledge of the curriculum, teaching strategies, learning misconceptions and the learning context. There were indications of good knowledge of the curriculum because the participant managed to discuss what learners needed to know and the objectives of each big idea. However, the teaching strategies needed to be implemented seemed to be a challenge as the participant discussed a single teaching strategy for each big idea. According to the master CoRe, a single teaching strategy is not sufficient to teach a lesson.

Through the classroom observation, the ePCK of the participant was described. The curricular knowledge was evident as the participant taught relevant content during the observation. multiple teaching strategies were used during the observation, which improved the likelihood of reaching the lesson's objectives. Some areas of the lessons need improvement. The testing of a three-phase motor was not presented during the lesson. Thus, the participant's enactment of his PCK was not fully described under three-phase induction motors.

The participant's PCK was described through the use of the interview and observation. The participant could present most of the discussed content. However, some parts were incompatible. The participant used multiple teaching strategies during the lesson presentation (i.e., the question-and-answer, direct instruction, and demonstration), but he described using one teaching strategy for the two big ideas discussed (i.e., direct instruction) and the questions that the participant used were not fully discussed during the interview.

4.8. CASE 6 – PARTICIPANT 6

Participant 6 was only interviewed and not observed. Table 4.5 below, represents the summary of participant 6 scores from the interview. The participant's scores are compared to the master CoRes and then used to determine whether the participant has sufficient or insufficient pPCK.

***Table 4.6**: Participant 6 interview and observation compared to the master CoRe.*

	Interview				Observation			
Component prompts	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Knowledge and skills related to curricular saliency			**X**					
Knowledge and skills related to conceptual teaching strategies			**X**					
Knowledge and skills related to students' understanding of technology			**X**					
Representations			**X**					
Questions not related to a certain component			**X**					

The "X's" in the table represent the scores attached to a specific PCK component based on the interview and observation discussions from Participant 6.

4.8.1. Interview 6

Curricular saliency

The participant's knowledge of the curriculum and how to reach its objectives will be discussed in this section.

For the construction of a three-phase induction motor, in the first prompt (A1) the participant's intentions on what learners need to know mirror those of the master CoRe. The participant stated, *"I want my* *learners to be able to know about the parts of the motor, the inner and the outer parts of the motor."* This shows an understanding of the construction of a three-phase motor as the participant further said, *"I just want them to know a function of each part of the motor. And what else do I want them to know? I want them to know how each part is connected to the motor."*

In the second prompt (A2), the participant's responses show a good understanding of the objectives of the curriculum. As stated below:

[I] think it's important for them to know about the parts of the motor because they can be able to understand each and every part of the motor *[sic]* what it does to the motor whenever it's operating. And as well they can be able to test if there's any fault they can be able to detect which part has a fault. And also they can be able to name the parts instead of not knowing which part is which one. Also, they must be able to identify the parts of a motor.

Excerpt 4.62: Objectives of the construction of a three-phase motor

This discussion is exactly what is found in the master CoRe. The importance of the concepts surrounding concepts in the curriculum is recognised and learners' comprehension of the environment around them is clear.

For the third prompt (A3), there is evidence of scaffolding and developing learners' knowledge from known to unknown. Using learners' knowledge of their 'previous grades' helps them develop critical thinking skills and simplifies the content. As stated by the participant:

[F]rom previous grades, they need to know about single-phase motors which they've *[sic]* done in grade 11. They are familiar with single-phase motors but now they'll be doing three instead of single-phase. And then what else do they need to know? I think they need to know assembly. Assembly of parts. Because after we teach them about the parts of the motor we want to take them out and they need to know how to assemble how they were. And then what else do they need to know? They need to know about the connection I think of the parts of connection of parts. I think that's what they need to know.

Excerpt 4.63: Evidence of scaffolding learning

Although some components of the master CoRe are missing, the participants' arguments indicate good curriculum knowledge.

For the last prompt (A4) under construction, the discussions did not mirror the master CoRe. The participant stated:

> I think what my learners don't know about the construction of the motor is that some of the parts are not electrically connected but they work through magnetism. So, I think they're not familiar with that concept. They don't know that some of the parts are not electrically connected but they work with the principle of magnetism.

Excerpt 4.64: What learners do not know yet

The focus was not on the construction but on aspects of the operational principle.

For the second big idea (The operational principle), the first prompt (A1) was understood as the participant discussed aspects that are found in the master CoRe. The participant responded to what is expected of learners by saying:

> [H]ow the motor works. The efficiency of the motor. How it starts. It's starting torque. How it starts. And the synchronous speed as well as the rotor speed.

Excerpt 4.65: What learners need to know about the operational principle

Most of the aforementioned aspects are part of the master CoRe. This extract above indicates the curricular knowledge of the participant.

In the second prompt (A2), the participant responded by identifying aspects that learners would need when pursuing a career in electrical engineering. This response indicates the knowledge of the objectives of the curriculum. The participant stated:

> [S]o that they can be able to fix the motor. I will say that they can be able to operate the motor. So that they can be able to understand the motor itself. Okay. Because they are going to use it even afterwards, after completing grade 12. When they do electrical engineering, they're still going to work with bigger, even bigger, or smaller motors. So, this is what they are going to face on *[sic]* daily basis. So, they have to know how it works. So that they can identify as well as the faults on the motor. Fault finding.

Excerpt 4.66: Objectives of the operational principle

The discussion in the extract also indicates the importance of scaffolding as learners need to troubleshoot a motor and understand what may cause a danger in the operation.

In the third prompt (A3), knowledge of the curriculum was demonstrated by the participant's response. The prior knowledge needed by the learners to fully understand the principle of operation of a three-phase motor was articulated perfectly. Evident in the participant's statement below:

> I think you need to teach them about the principle of magnetism. The principle of magnetism. And then all the laws that are needed Faraday's law. And what else that you need to teach them? you need to teach them about the construction. I think the construction of all the parts so that they can know how does *[sic]* each part contribute *[sic]* to the function of the motor.

Excerpt 4.67: Learner prior knowledge of the operational principle

The responses were consistent with the master CoRe in every aspect.

For the last prompt (A4), the participant said *"What I will teach them at the later stage is how to change the rotation of the motor. I think it must come at the end after they understand how it works."* The direction of rotation is an aspect to be taught later, according to the master CoRe.

Concerning the testing of a three-phase induction motor, in the first prompt (A1), the participant mentioned some aspects that are part of the master CoRe. As evidenced *"I want my learners to know how to test the insulation resistance between the windings and then, how to test the connection of the motors, the connection of the windings."* Only one test was not mentioned that forms part of the master CoRe. The participant later added *"There are three tests basically. The insulation resistance to the windings and the other one has to do with the earthing of the motor. The continuity resistance test."* These are all the tests to be performed according to the master CoRe and the curriculum.

For the second prompt (A2), the identified concepts form part of the master CoRe. The participant is demonstrating signs of good curricular knowledge. As indicated below:

> [S]o they can be able to identify any fault. Between the motor and the windings. And they're able to test the motor before they can even operate it. Yeah. Before you even switch it on, they're able to test it first if everything is okay.

Excerpt 4.68: Objectives of testing a motor

In the third prompt (A3), the participant indicated exceptional knowledge as not only the prior knowledge of the learners was taken into cognisant, but the exercise learners need to do before testing a three-phase motor was also explained. Evidenced in the statement below:

[I] think you need to teach your learners how to use the testing equipment that they'll be using to test the motor. Which is the megger tester. They must be familiar with it. know how to use it before they can even test the motor. And then you need to teach them about the connection of the windings within the motor. When they open the connection box, they need to see which one goes with the other one and which one goes with the other one. The pairs of the windings.

Excerpt 4.69: Prior knowledge about the testing of a three-phase motor

This response mirrored the recommendations of the master CoRe and provided evidence of the participant's knowledge of scaffolding.

In the last prompt (A4), the participant identified concepts that were inconsistent with the master CoRe. As stated below:

[I] think you need to teach your learners how to use the testing equipment that they'll be using to test the motor. Which is the megger tester. They must be familiar with it. know how to use it before they can even test the motor. And then you need to teach them about the connection of the windings within the motor. When they open the connection box, they need to see which one goes with the other one and which one goes with the other one. The pairs of the windings.

Excerpt 4.70: Knowledge of scaffolding

When teaching learners how to use the test equipment, you must also teach them how to interpret the readings they obtain from the tests.

What makes a topic easy or difficult to understand?

In this section, I focused on the transformative factors that helped or impeded the participant's educational goals.

For the construction of a three-phase motor, the challenging part for the participant is not similar to the challenge in the master CoRe. The participant stated below:

[I] think what I'm struggling with is understanding the connection of the terminal box of the windings before the testing part. I think it's the connection of the terminal box of the windings before the testing part. What else? That, I think my learners have a challenge on.

Excerpt 4.71: Challenges faced by the teacher

The study of the operational principle is comparable to the notions in the master CoRe. Although some ideas are not addressed, all the concepts described are from the master CoRe. The following is what the participant said:

[I] think the learners need to understand the laws first before they can understand the basic operation. So, they don't understand the laws of for instance, like for instance Faraday's laws all those laws that we need to know before we can actually know the operation of the motor. So, I think they don't understand them first. All those rules that they need to understand before we tackle the topic.

Excerpt 4.72: Challenges faced about the operational principle

The participant's focus is only on what learners find challenging to understand and does not include the teacher's challenges.

For the testing of a three-phase induction motor, the participant mirrored the concepts discussed in the master CoRe. The participant stated:

[W]hat do I consider difficult? I think the safety usage of the testing tool and again I think what is difficult is the amount of voltage which we put there. It's difficult because we work with the [sic] learners who can do some of the things with the testing equipment. So, I think we need to be careful as teachers when we use that testing equipment. So, the voltage when we test the motor is too high. Those are some of the challenges that will face because now we are dealing with three-phase. We need to put twice the voltage that the motor has.

Excerpt 4.73: Challenges on the testing of a three-phase motor

The participant mentioned safety and learners' challenges in using the insulation tester.

Learner Prior Knowledge

In this section, I emphasised the significance of learners' past knowledge and how it contributed to a deeper understanding of three-phase induction motors.

Misconceptions noted by the participant relate to learners believing that all the parts of a three-phase induction motor are electrically connected. In the statement below:

[T]hey think that all the parts of the electrical motor work with the electricity. So, before you teach them about the operation that is what they think until you let them know that the operation is totally different to how they thought things were.

Excerpt 4.74: Misconceptions about the construction

These discussions about the construction of a three-phase motor are inconsistent with the master CoRe.

The misconceptions noted by the participant under the operational principle are related to the magnetic field. In the statement below:

My learners, they *[sic]* think that because now when you open the inner part of the motor, we are not able to see the magnets or the magnetic poles within the stator. They find it difficult to understand how is it possible that it works with the principle of magnetism while they don't see the physical magnets on the stator of *[sic]* the, of the motor. So, I guess you just need to explain to them that they are there even though they are not able to see them, but they are there. That is how it makes the rotor to *[sic]* turn.

Excerpt 4.75: Misconceptions about the operational principle

The discussions are consistent with the master CoRe, as learners are confused by the cause of the rotor's rotation.

The misconceptions experienced by learners during the testing of a three-phase motor are based on the usage of the insulation resistance tester. Learners are not cognisant of how to set the meter for testing. As the participant explained:

[I] think because they look at the nameplate of the motor when *[sic]* before you can even tell them that they need to put the voltage to 1000. They think that because it's 400 volts they need to use 500 volts on their test. Or if it's 400 it's there then they put 400 because they don't know that you have to put twice the voltage on their test that. So, they think that they have to put the exact reading that they see on the nameplate of the motor as the same they say it's the same reading when they test.

Excerpt 4.76: Misconceptions about the testing of a three-phase motor

This misconception is consistent with the master CoRe, as it relates to the challenges of interpreting the results of the test.

Conceptual Teaching Strategies

In this section, I focused on what motivates Participant 6 to reconsider their educational approach, thinking about how to provide learners with cognitive skills to absorb, question, and synthesise knowledge on their own.

For the construction of a three-phase motor, the teaching strategies selected by the participant are not consistent with the master CoRe. The participant described one teaching strategy. As described below:

[I] will use a physical motor that we no longer use. An old motor. Dissemble all the parts. Show them one by one. Each part and explain each function of the part. Dissemble all the parts of the old motor that we are no longer using.

Excerpt 4.77: Teaching strategies for the construction of a three-phase motor

This description will cater for a few learners and might lead to several learners not becoming interested in the lesson.

The questions asked during this teaching strategy are consistent with the master CoRe. The participant said *"Identify the parts of a three-phase motor. Which are similar to the single-phase motor because I believe that they've already done the chapter. So, some of the things they might be familiar [sic]. It would be something new."* The questions assist learners in developing critical thinking skills and they encourage scaffolding.

For the principle of operation, the teaching strategies described by the participant are consistent with the master CoRe. As stated below:

Okay. Because now the operation you can't teach your learners without them seeing the physical video. I think it's important for any teacher to use an overhead projector whereby the learners will be able to see the inner part of the motor in a *[sic]* form of a video, rather than explaining to them the theoretical part which they are not able to see with their naked eyes. So, a video is better than telling them something that they will not be able to see. Because even if you can tell it on, they will not be able to see what is happening inside the motor, but once you use a video, a video will be able to show them what is happening to the rotor, the state, the parts within them won't. So, I think a video will be user-friendly for you to explain to the learners. Rather than reading them a theory part in which they are not even able to see.

Excerpt 4.78: Teaching strategies for the operational principle

The participant's description drew focus on direct instruction and demonstration as the main teaching strategies. Learners are encouraged to analyse, evaluate, and synthesise information when they are exposed to multiple approaches to an issue or topic, which can lead to a deeper level of thinking (Facione, 1990).

The questions that the participant plans to ask regarding the principle of operation are consistent with the master CoRe. The questions encourage scaffolding and promote critical thinking from the learners. from the statement below:

[I]'ll ask them about the *[sic]* Fleming's left-hand rule. Is it left, or right? I think it's *[sic]* right hand. Right-hand rule. That will help me to address the importance of them knowing the direction of the magnetic field lines because now the concept or the operation of the motor is based on magnetism. So, they need to know each and everything to do with magnetism. And I will also ask them about the principle of magnetism from grade 10 which is something that they are familiar with. So, it's not something that they start in grade 12. And then what else will I ask them? The questions that I will ask my learners *[sic]* is where do they think we see motors? Where do we use them? Where have they seen them?

Excerpt 4.79: Questions planned for teaching the construction of a three-phase motor

The focus of the above discussion is on learners' understanding of the magnetic field.

For the last big idea (testing of a three-phase motor), the teaching strategies selected are demonstration and direct instruction. The strategies are described below:

[S]trategies that I will use. I will start demonstrating first *[sic]* how can they use the equipment or demonstrate first. Before I can give them the equipment because the amount of voltage that we use is 1000 which might be dangerous if learners play with the leads of the megger tester. So I was that demonstrating showing them first before they can actually do it so that they can know what is it that is expected from them. And what else can I use? I think I can also use a video. I can use a video by they see a person and *[sic]* testing a motor and what else I can use. I think because they are familiar with testing a single-phase motor it won't be a challenge that much because already, they have that simulation whereby they tested a single-phase motor in grade 11 but now it's no longer single it's three-phase. So yeah. It's not something that is new.

Excerpt 4.80: Teaching strategies for testing a three-phase motor

The strategies described in the extract above are sufficient to help develop learners' analytical thinking skills and better their quality of education.

The questions to be asked by the participant in the testing of a three-phase motor are consistent with master CoRe. First, the participant asked *"Questions that I think are very important. I will ask them what readings do [sic] they get between the windings which are connected which [sic] what readings are they getting or their megger tester."* The question will improve the learners' understanding of the topic, but it is not sufficient alone. The participant later added:

> [A]nd then what else will I ask them? I will ask them before they can even test the type of connection in *[sic]* which the motor is connected. Is it Star or Delta? Do they know if it's *[sic]* star or delta or show them first all those things? The type of connections that the windings have. And then I will ask them after inspecting the motor, from the readings which *[sic]* they got is it safe for us to operate the motor? Is the motor acceptable to operate or it's not acceptable? And they must give me the reasons why they think the motor is not acceptable. To be operated by people or industries or whoever will use the equipment.

Excerpt 4.81: Questions asked for testing a three-phase motor

These additional questions are sufficient for learner development, and they are consistent with the master CoRe as they focus mainly on the usage of measuring instruments used for this topic.

Representations and analogies

For the construction of a three-phase motor, the participant has a great understanding of representations that are going to become effective in the classroom. The participant said:

> [T]eaching media. Now I will have a physical motor as well as *[sic]* projector. I will use an overhead projector. They also have a motor panel which consists of different types of motors, both single and three-phase which they can use.

Excerpt 4.82: Representations used for the construction of a three-phase motor

These representations are consistent with the master CoRe and are sufficient to improve the learning experience.

For the principle of operation, the selected representations showed exceptional knowledge of the curriculum and skills for enhancing the learning experience. The participant stated:

[T]eaching media is a projector, *[sic]* YouTube videos for them to watch. Select the ones that I think that *[sic]* will be able to link with the prior knowledge that they have. I'll break them down easily, step by step so that I can see that this one must be *[sic]* first, second one, and so forth.

Excerpt 4.83: Representations for teaching the operational principle

The discussed representations are consistent with the master CoRe. The participant also explained how the media will be used to improve the impact.

In the testing of a motor, the selected representations were consistent with the master CoRe. The participant stated:

[I] will use a motor. A physical motor, It *[sic]* must be there. And then it must be disconnected from the supply because we work with safety first. And then I will also use a megger tester as well as a video.

Excerpt 4.84: Representations of testing a three-phase motor

The discussion above shows an understanding of the teaching media and how to use them. The participant also added *"And Also [sic] I can demonstrate first. So that they can know what is expected from them."*

Additional Questions not linked to a specific component.

The assessment mentioned under the construction of a three-phase induction motor is consistent with the master CoRe. In the statement below:

[I] will use their activity book as well as I can give them a task to assemble the parts of the motor after we disassemble them. They can assemble them back so that I can test if they do understand where each parts *[sic]* is supposed to be. So, they can take the parts back to where they *[sic]* how they may before we assemble the motor.

Excerpt 4.85: Assessment for construction of a three-phase motor

The participant displays a sound knowledge of assessment and how to use it for maximum impact.

The assessments discussed for the principle of operation at first were insufficient as the participant said *"I'll use a previous question paper. Ask them to write the principle of operation of a motor."* The statement forms part of a good assessment if used only with other questions. The participant later added:

[A]sk them to write the principle of operation of the motor. Also, they can also use their practical assessment task simulation. They can answer questions from there after completing the activity of the operation. I'll select some activities from the practical assessment task, which are based on the operation of the motor.

Excerpt 4.86: Assessment used for the operational principle

With the added extract above, the assessment is now consistent with the master CoRe because the added PAT has questions that promote critical thinking skills and are valuable for formative and summative assessments.

For the last big idea (testing of a three-phase motor), the participant focused on assessments that included practical testing skills. the participant stated:

[I] will use the practical assessment task which my learners have where they are required to test the motor. And as well, I can give them a physical motor and they test it while I'm looking at what they are doing.

Excerpt 4.87: Assessments used for testing a three-phase induction motor

This response is consistent with the master CoRe, as the PAT task contains the usage of the test equipment and the interpretation of the test results.

4.8.2. Summary of Participant 6's PCK (Case 6)

I was able to describe the teacher's pPCK of three-phase induction motors through the interview, using the teacher's responses. The teacher displayed curricular knowledge, learning context, teaching strategies, assessment knowledge and learner knowledge. Aspects that were fully described during interviews are learner misconceptions, using scaffolding and difficulties in teaching the topic. The participant displayed a deficiency of knowledge about teaching approaches, as a single strategy was selected to teach the topic. According to the master CoRe, more than one teaching strategy is needed to present a lesson.

The ePCK was not described as the teacher was not observed. Thus, a comparison of the pPCK and ePCK of the participant cannot be drawn.

4.9. SUMMARY

In this chapter, I presented the results of the study. I began by presenting each of the six participants' interview discussions per big idea. These discussions were analysed and compared to the master CoRe. Analysis of these interviews focused on the use of teaching approaches, curriculum knowledge, prior knowledge, identification of misconceptions and knowledge of assessment. The interview analysis provided information to help me describe the participants' pPCK for three-phase induction motors. The pPCK was then compared to the ePCK from the classroom observation analysis. These observations and analyses thereof, provided information about the participants' ePCK. There was a clear comparison which reflected similarities and differences between the participants' pPCK and ePCK. This comparison assisted me in comprehending the participants' preparation and presentation on the topic.

The results indicated that these participants have a sound knowledge of the curriculum as they could describe what needs to be taught under the three big ideas, the required prior knowledge to simplify the topics and learning difficulties about the topics. The difficulties experienced by the participants were also discussed. Most participants experienced a challenge in selecting the correct teaching strategies during the interviews, yet they were all able to use different, useful strategies during the lesson presentations.

In Chapter 5, I assess the study's outcomes by comparing them to previous research. I examine the study's findings before returning to the research topics from Chapter 1. After that, I discuss the study's shortcomings before concluding the chapter with suggestions for workshops, practice, and future studies.

5. CHAPTER 5: SUMMARY, LIMITATIONS AND RECOMMENDATIONS

5.1. CHAPTER OVERVIEW

This chapter summarises the previous chapters, explains how the research subjects were handled, and reports the findings of this study. I explain these findings in light of past studies on PCK. Following my findings, I highlight the potential hypothetical, methodological, and actual benefits of this research. I emphasise a framework for electrical technology teachers to design teaching methods for three-phase induction motors, which was one of the study's goals (see Section 1.5). This chapter concludes by discussing the potential limitations of my study and how I have addressed them. Thereafter, recommendations for further research are provided.

5.2. OVERVIEW OF THE STUDY

Lee Shulman (1986) pioneered the idea of pedagogical content knowledge (PCK). It is described as the combination of pedagogy and content, encompassing both the 'what' and 'how' of teaching (Shulman, 1986). PCK distinguishes between understanding something and knowing how to assist others in comprehending it (Magnusson et al., 1999). It entails comprehending learners' assumptions and mental processes, teaching tactics, curricula, and assessment procedures (Magnusson et al., 1999).

Multiple worldwide studies have demonstrated that teachers have a crucial impact on learner success, and PCK is considered the essence of good teaching (Darling-Hammond, 2000). Teachers with sufficient PCK understand what makes an idea difficult to grasp, how to best represent things, explain concepts, and break down obstacles to learners' comprehension (Darling-Hammond, 2000). However, building PCK may be challenging for teachers, and learning from experience is an important part of their journey (Darling-Hammond, 2000).

Research on PCK growth in future teachers is extremely important (Loughran et al., 2008). Successful approaches for PCK development often include review, PCK courses, communication with other teachers, and experiences in educational practice (Loughran et al., 2008). These interventions help accelerate the transition from novice teacher to expert, minimising the potential harm to students' learning during those formative stages (Loughran et al., 2008).

In Chapter 1, I provided the focus of my study on PCK of electrical technology teachers in the three-phase induction motors chapter. Thus, the purpose of my research was to investigate electrical technology teachers' PCK to improve their pPCK and ePCK. I achieved this by interviewing and observing electrical technology teachers using the CoRes adapted by Coetzee (2018) and measuring the teachers' PCK using a rubric first used by Zimmerman (2015).

In Chapter 2, I gave an overview of knowledge and what eventually leads to PCK. The pPCK and ePCK were discussed along with the PCK components that make up the CoRes. This was followed by the adapted CoRes and how PCK was assessed in this study. Thereafter, the conceptual framework that guided my study was discussed and analysed.

In Chapter 3, I focused on the design and methodology. I discussed interpretivism's paradigmatic approach, qualitative research, single case study, non-probability sampling, data collection techniques and documentation, data collection instruments, interviews, observations data analysis and interpretation, standards of rigour, ethical considerations, the data, the participants, research benefits and permissions. Justifications for my choices were also provided.

In Chapter 4, I presented and discussed the ePCK and pPCK results of electrical technology teachers based on interviews and classroom observations. I presented the electrical technology teachers' PCK using an updated CoRe model that emphasised curricular relevance, conceptual teaching tactics, and students' comprehension of technology. The electrical technology teachers exhibited their pPCK by answering research questions during interviews, and their ePCK was observed while teaching the three-phase induction motors chapter. Through this chapter, I provide extracts of transcripts from interviews and data from observations that reinforce my arguments.

5.3. FINDINGS OF THE STUDY

In this section, I offer the study's findings by placing them in combination with the master CoRe created with the assistance of an electrical technology topic specialist as per the DoBE (2014). Table 5.1 presents the study's outcomes, organised according to the key principles presented in Chapter 4. I finish this chapter with a review of the findings and conclusions obtained about the sub-research questions stated in Chapter 1.

***Table 5.1**: Electrical Technology teachers' PCK in comparison with the master CoRe*

Electrical Technology teachers' PCK of three-phase induction motors in comparison with the master CoRe		
Theme 1: Knowledge and skills related to curricular saliency		
A1. What do you intend for students to learn about this idea?	For the first big idea, •The three main parts of a three-phase motor are the stator, the rotor, and the stator windings. •In a three-phase induction motor, the stator is the static portion that contains the stator windings. •The rotor is the rotating component of a standard squirrel-cage induction motor. It consists of a steel lamination cylinder with aluminium or copper wires embedded on the outside. •A three-phase set of motor windings is inserted into the stator metal slots. The windings can be connected in a wye (star) form, which frequently does not require a connection outside to the neutral point, or in a delta design. •The types of three-phase induction motors.	For the first big idea, the teachers could respond consistently with the master CoRe. Only a few could not fully express their understanding of the requirements of the big idea.
	For the second big idea, • When a three-phase supply is linked to a motor, a revolving stator field is automatically formed. •The rotating stator field cuts the metal rods of the rotor inducting a large current in them. •The induced current creates its rotor magnetic field. •The rotor magnetic field and the stator field interact with each other. A force called torque Is then generated between the two fields.	For the second big idea, the teachers could provide the operational principle. One teacher expressed how the usage of the old textbook was useful in making learners understand the operational principle.

	• The rotor begins revolving in an identical direction as the revolving stator field. •As the speed of the rotor increases, less current is induced in the rotor.	
	For the third big idea, •Perform visual inspection on a three-phase motor to identify faults. •Performing the insulation resistance test between windings •The insulation resistance test between windings and earth. •Safety when testing. •Continuity/resistance test.	For the third big idea, the teachers' responses were consistent with the master CoRe. The teachers could fully describe the requirements of testing a three-phase motor.
A2. Why is it important for students to know this?	For the first big idea: •To identify the main parts of a three-phase induction motor. •To test a three-phase induction motor. •To use three-phase motors. •To deduce the benefits of three-phase motors related to single-phase motors	For the first big idea, the teachers' responses were consistent with the master CoRe. Most of the teachers could explain the importance of the construction of a three-phase motor.
	For the second big idea: •To explain the cause of the rotor to rotate in a motor. •To explain how torque is generated in a three-phase motor. •To link the speed of rotation to the induced current in the rotor. •To differentiate between the rotor speed and the synchronous speed.	For the second big idea, teachers identified knowing the effects of a magnetic field as an important section for learners to understand.
	For the third big idea •To identify faults in a three-phase induction motor and any other machine.	For the third big idea, most teachers' responses were centred around

	•To interpret the results from the tests performed. •To protect people from harm that may be caused by a faulty motor. •To commission a motor.	safety in testing. Stating that electricity is dangerous and safety must be of priority.
A3. What concepts need to be taught before teaching this idea?	For the first big idea •The operation of a three-phase system •Star and delta connections •Identifying parts of a single-phase induction motors For the second big idea •Principles of magnetic fields •Self and mutual induction •Faraday's law For the third big idea •Usage of the Ohm meter and the insulation meter. •Safety when using the test equipment.	For the first big idea, the teachers' collective responses mirrored the master CoRe. Most teachers saw a need for learners to identify the parts of a single-phase motor as it supports the learning of three-phase motors. For the second big idea, the teachers perceived self and mutual inductance as important parts to support the understanding of the operational principle. For the third big idea, safety was heavily emphasised as the motor uses high electrical current which is dangerous.
A4. What else do you know about this idea	For the first big idea, Losses of a three-phase induction motor and Slip For the second big idea	The teachers found nothing should be taught at a later stage for all big ideas.

(that you do not intend learners to know yet)?	•The speed of the rotor is inversely proportional to the current induced in the rotor, but the current induced in the rotor cannot be zero as there will be no torque produced. •How to change the direction of rotation. For the third big idea nothing	
Electrical Technology teachers' PCK of three-phase induction motors in comparison with the master CoRe		
Theme 2: Knowledge and skills related to conceptual teaching strategies		
B1. What do you consider difficult about teaching this idea?	For the first big idea • The terminologies are not part of learners' daily lives, thus making them challenging to understand.	The teachers noted the language as the major barrier to learning about the construction of three-phase motors.
	For the second big idea • The terminologies are not part of the learners' daily life. Their knowledge of magnetic forces is limited to permanent magnets. •The operation of an induction motor is an abstract concept. •Learners find it difficult to grasp how two magnetic fields moving in opposite directions cause a force.	For the second big idea, the language was also noted as the major barrier by most teachers. The principles of magnetism which were taught in the previous grades are also noted as a barrier since they form part of the operational principle.
	For the third big idea •Explaining how to interpret the reading of the resistance test and the insulation resistance test.	For the third big idea, the usage of the meters was noted as a barrier to

		learning. Language usage was also noted as a barrier to learning.
D1. What effective teaching strategies would you use to teach this big idea?	For the first big idea •Direct instruction and cooperative strategy as most of the subject is practical based. •Visual representation. For the second big idea •Direct instruction and cooperative learning. •Visual representation. For the third big idea •Direct instruction and problem-solving strategies will be used. •Use the Ohm meter and a motor to demonstrate how the test is performed. Readings will be recorded and interpreted to improve learners' understanding. •Use the insulation resistance tester on a motor to demonstrate how the test is performed. Then the readings will be recorded and interpreted to improve learners' understanding.	For the first big idea, the teachers opted for the direct instruction teaching strategy paired with visual representations. For the second big idea, direct instruction and visual representations were the more favoured teaching strategies. For the third big idea, the teachers perceived direct instruction and demonstration as the most effective methods since this section of the topic forms part of the Practical Assessment Task (PAT).
D2. What questions would you consider important to ask in your teaching strategy?	For the first big idea •Ask what a motor is before explaining the main parts. •Before explaining the function of the stator, ask the learners what they understand about the stator of the motor. •Ask what laminations are before explaining the function of the stator.	For the first big idea, the questions mainly asked are to check if learners are paying attention. The teachers perceived questioning as a form of formative assessment and the

(Original CoRe: teaching procedures)	•Ask learners what the effects of frequency on synchronous speed are. •What information do we get from a motor's nameplate?	questions asked during the lesson were mainly used in their assessments of the section.
	For the second big idea •Explain the concept of mutual induction. •How is a rotating magnetic field generated? •Ask learners why a three-phase motor is self-starting since learners know how a three-phase magnetic field is generated.	For the second big idea, the teachers mainly focused on asking questions regarding the full operational principle of a three-phase motor.
	For the third big idea •What does an Ohm meter measure? •How is an Ohm meter connected? •How is an insulation resistance tester connected?	For the third big idea, teachers focused on questions that mirrored the master CoRe. Additional questions like the types of inspections performed on a three-phase motor were asked.

Electrical Technology teachers' PCK of three-phase induction motors in comparison with the master CoRe		
Theme 3: Knowledge and skills related to students' understanding of technology		
C1. What are typical students' misconceptions when teaching this idea? (Original CoRe: Knowledge about students' thinking that influences your teaching of this idea)	For the first big idea •Learners believe the stator is the frame of the motor. •The rotor of the motor is often seen as a solid cylindrical metal.	For the first big idea, the teachers found that the learners misuse the terminologies in three-phase induction motors. When first faced with the chapter, learners often think about the engine of a car rather than an electric motor.
	For the second big idea •Learners believe that the current causes the rotor to rotate and not the magnetic field.	For the second big idea, teachers found that learners believe the rotor is directly connected to the supply and thus the rotation is directly caused by the current.
	For the third big idea •Learners cannot differentiate between the insulation resistance test and the resistance test. •The two tests are interpreted the same way.	For the third big idea, teachers perceived that learners only perform the continuity test and believe it is similar to the insulation resistance test.

Electrical Technology teachers’ PCK of three-phase induction motors in comparison with the master CoRe

Theme 4: Representations

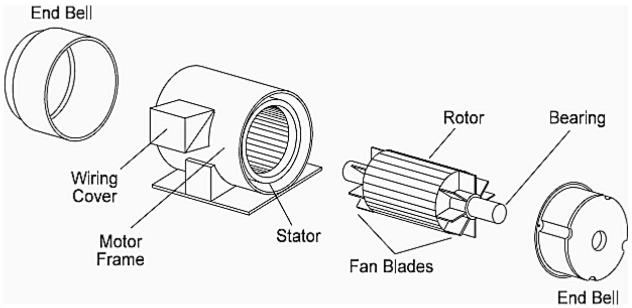
E1. What representations would you use in your teaching strategy?

For the first big idea

•Animated video about parts of a motor.

•Using a real motor to identify the parts.

•Diagrams:



For the first big idea, teachers focused on the usage of a textbook as a teaching aid along with YouTube videos, pictures and charts.

For the second big idea

•Since this is an abstract concept a video explaining using animations will be used to simplify the concepts.

For the second big idea, teachers mostly focused on using YouTube videos to help explain how magnetism causes the rotor to rotate.

For the third big idea

•A model of a three-phase induction motor will be used for testing.

•Videos

•Multimeter and the insulation resistance tester

For the third big idea, teachers perceived YouTube videos as the most important representation above all else. Then after using the multimeter and the insulation resistance tester.

Electrical Technology teachers' PCK of three-phase induction motors in comparison with the master CoRe		
Theme 5: Additional Questions not linked to a specific component		
What ways would you use to assess students' understanding (original CoRe: Specific ways of ascertaining understanding)	for the first big idea •Give learners a diagram for them to name the main parts of a motor and describe their functions. •Give learners an exercise on explaining the synchronous speed, rotor speed and slip.	For the first big idea, teachers perceived naming the parts of a three-phase motor as important and also focused on using the textbook for assessment.
	For the second big idea •Give learners an exercise in explaining the basic operation of a three-phase induction motor	For the second big idea, some teachers focused on making sure learners understand the construction first as it forms a foundation for understanding the operational principle and the usage of textbooks for assessment was not discarded.
	For the third big idea •Give learners an exercise on interpreting the results from the insulation resistance test and continuity test. •Use previous exam question papers.	For the third big idea, the teachers focused on using the textbook and mini-tests for assessment. Individual practical assessment was perceived to be effective as learners need to be given a skill of testing.

5.3.1. Research question 1: How can electrical technology teachers' pPCK of three-phase induction motors be described?

The primary conclusions surrounding this study topic were that these teachers' pPCK revealed through interviews requires development. The findings are largely because these teachers identified appropriate ideas and linked them to the big ideas and the definitions provided are within the master CoRe. The teachers displayed limited knowledge regarding topics that needed to be taught before teaching the operational principle. The findings also showed that the reasons provided by the teachers included some evidence of conceptual scaffolding and knowledge of the curriculum regarding the construction and testing of a three-phase motor.

More findings related to what makes the topic challenging to teach are that these teachers' pPCK needed development. This is partly because these teachers demonstrated adequate difficulty relating to one of the big ideas. The teachers also displayed a need for development regarding the best teaching strategies to be used for the big ideas. A list of general strategies was given by most teachers and in other cases, the suggested strategies were inadequate for the big idea. Furthermore, the questions used in the given teaching strategies only focused on fluency and not critical thinking.

To further support these findings, representations were adequately selected; however, there was no evidence of how to use them to lead to an increased understanding. Several teachers discussed representations but did not explain the exact ties to the topics being investigated. This inconsistency in teachers' responses leaves room for further research to investigate the teachers' pPCK in electrical technology.

5.3.2. Research question 2: How can electrical technology teachers' ePCK of three-phase induction motors be described?

The key findings related to this topic were that these teachers' ePCK described through lesson observations need development. This is because although the teachers could plan and present the lessons, crucial information was out for all the big ideas. The curricular saliency needs development because the teachers could not fully teach all the curriculum objectives, they could not explain the purpose of the content to the learners, and they could not help learners recall their previous year's content to create an understanding of the new topic. These could not be able to display any knowledge of scaffolding during their presentation as the big ideas were not linked logically. The teachers also did not present the pre-concepts needed for the lesson. This lack of identification led to the illogical placing of concepts during the presentation.

To further support these findings, appropriate difficulties were identified for at least two big ideas, that were not addressed during the presentations. The overall teaching strategy was visibly effective, as the teacher kept asking questions to check for understanding. The teaching strategies also encouraged learner involvement in the lesson. However, the questions only promoted learner involvement and not higher-order thinking. There was also some evidence of how to use representations to support conceptual development. This evidence of conceptual development was not evident for the third big idea. For some teachers, an overview was given during the lesson observations. Questions were not asked; the testing tools were not used, and learners were not assessed on the last big idea.

The findings of this study may contribute to the development of novice teachers in their understanding of three-phase induction motors. Understanding the unique problems and capabilities of electrical technology teachers' ePCK might help shape focused professional development programmes. These programmes can give teachers the assistance and tools they need to improve their pedagogical abilities, resulting in better learner results. Further study may be required to describe the ePCK of a greater number of electrical technology teachers.

5.3.3. Research question 3: How do electrical technology teachers' pPCK and ePCK of three-phase motors compare?

Based on the results of this research, these teachers' pPCK and ePCK do not compare. The pPCK and ePCK of these teachers demonstrate the developing character of their PCK, emphasising the importance of continual support and professional growth. There are a few differences between the teacher pPCK and ePCK. What the teachers discussed during the interviews did not match how they presented their lessons. The teachers discussed teaching strategies and the teaching strategies observed were different. Some teachers did not present all three big ideas during the presentation, this may have been caused by insufficient lesson time. The questions asked during the presentations and the ones given during the observation were dissimilar. There is a misalignment in the lesson planning and presentation, suggesting that the teachers may have basic knowledge about lesson planning or that they do not plan at all. Other factors may include differences between levels of CK and pedagogical skills, impacting the teachers' ability to translate theoretical knowledge into practice.

These findings suggest that the teachers' lesson plans differ from what they teach in the classroom. While some aspects of the pPCK and the ePCK are well-compatible, the teachers managed to teach the three-phase induction motors chapter with significant differences from what was initially observed through interviews. The teachers managed to use the representations that were in the classroom. The teachers asked questions and received positive responses towards most questions. With these similarities and differences in teachers' pPCK and ePCK, we can conclude that a teacher's pPCK may not be fully described using interviews.

5.4. CONTRIBUTIONS TO THE STUDY

The contributions of the research are presented in this section. The main research question posed in Chapter 1 *(How do electrical technology teachers' pPCK and ePCK of three-phase induction motors manifest in the classroom?)* is answered by explaining its theoretical contribution. I also highlight the study's potential professional and practical benefits for technology education.

5.4.1. Theoretical contributions

To address the main question of the study, according to the findings of this study and in terms of pPCK, teachers' awareness of the underlying concepts, applications, and frequent misconceptions about three-phase induction motors informs their instructional planning. This involves selecting relevant information and creating instructional activities that are linked with curricular objectives. Teachers with good pPCK can apply a range of teaching approaches, including demonstrations, simulations, and hands-on experiments, to successfully convey motor operational principles.

ePCK is exhibited in teachers' classroom methods and interactions with learners. Teachers' ability to successfully express complicated concepts about three-phase induction motors, clarify ambiguities, and give scaffolding help reflects their current PCK. Teachers use dynamic conversations, thought-provoking questions, and problem-solving exercises to implement PCK in the classroom. In this study, teachers manifested signs of a need for PCK development in three-phase induction motors. The teachers' pPCK and ePCK were insufficient according to the master CoRe used as a rubric. The interviews and observations revealed that teachers need content development, planning and preparation, usage of teaching media and teaching approach development.

According to Shulman (1986), PCK is the junction of subject knowledge and pedagogical knowledge, in which teachers understand how to teach certain topics successfully. With three-phase induction motors, teachers' pPCK may include knowledge of motor concepts, typical learners' misconceptions, and successful teaching techniques for teaching motor operation and problem-solving. The findings of this study can help shape curricular frameworks for electrical technology education. By identifying areas where teachers have good or poor PCK, curriculum designers can prioritise material and pedagogical practices that enhance effective teaching and learning. Understanding teachers' PCK can help build assessments that effectively measure both topic knowledge and pedagogical skills in electrical technology education. This can ensure that assessment techniques are consistent with instructional goals and provide useful feedback for teacher development and learner learning.

5.4.2. Contributions of this study to technology education

The findings of this study provide insight into electrical technology teachers' pPCK and how they enact it in a classroom. This study may benefit grade 12 electrical technology teachers and educational stakeholders. University lecturers involved in teacher training for electrical technology may use these findings to develop programmes that will focus more on the development of novice teachers' ePCK.

5.5. HOW I HAVE ADDRESSED LIMITATIONS OF THE STUDY

According to Maree (2019), the purpose of qualitative research is to understand the behaviour of the persons engaged rather than to generalise the findings to the entire community. As a result, the first drawback is that the results of this research are confined to those who participated. The second drawback is that this investigation cannot be replicated using different research methodologies since the questions that led to it were only answered using a case study research method (Maree, 2019). The third drawback is that there were no incentives for the teachers who participated in this research. This may be the reason some teachers did not complete all three big ideas during observation. The final limitation is the researcher's bias. As an electrical technology teacher, the researcher has his own opinions on how the construction, the operational principle and the testing of a three-phase motor should be taught. This belief may influence the way the researcher assesses the quality of teachers' PCK.

5.5.1. Level of transferability of the study

The observations and interviews for this study were conducted primarily in Grade 12 electrical technology courses in Pretoria and Johannesburg, Gauteng. As a result, the conclusions of this study may only be relevant to some electrical technology classrooms in South Africa, or globally. The objective of this research was not to generalise the results but to shed light on the PCK of electrical technology teachers.

5.5.2. Sampling and participants

The research was limited to six interviewees and five observations. The goal was to design a sample method and criterion that would allow me to choose participants who were representative of Grade 12 electrical technology teachers with experience teaching three-phase induction motors. I had significant difficulty in recruiting enough participants for my study. Despite my attempts to involve electrical technology teachers in this research, I could not obtain a significant number of experienced teachers. Despite difficulties in selecting acceptable participants and with data collection procedures, I followed all applicable rules to improve the trustworthiness and rigour of this study.

5.6. Recommendations of the study

The findings highlight the significance of investigating and analysing PCK across a variety of components that characterise it since competency in one component does not imply competence in others. Additionally, teachers' competencies should be investigated concerning a range of big ideas within the issue. CoRes were originally designed to assist teachers in communicating their PCK. However, for this study, the CoRes were insufficient for evaluating the PCK. Thus, teachers must be seen in action to assess the quality of their ePCK, as this is the PCK that ultimately influences learning.

Based on the findings of this study, recommendations for further research are for case studies replicating this study with a larger sample to improve transferability and generalisability. The new investigation must include different contexts, and documents such as year plans, work schedules, worksheets, lesson plans, and assessments. In addition, the classroom management strategies used by electrical technology teachers reflect their ePCK. Teachers' capacity to implement their PCK and improve student engagement and learning results is demonstrated by creating a supportive learning environment, encouraging student participation, and successfully integrating technology.

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APPENDICES

Appendix A: Interview Questions

Semi-structured interview questions

	Big idea 1	**Big idea 2**	**Big idea 3**
	Construction of a three-phase induction motor	The principle of operation of a three-phase motor	Testing a three-phase induction motor
A. Curricular Saliency			
A1. What do you intend students to learn about this idea? (In original CoRe) A2. Why is it important for students to know this? (In original CoRe) A3. What concepts need to be taught before this big idea? (Only in adapted CoRe) A4. What else do you know about this idea that you don't intend students to know yet? (In original CoRe)			
B. What makes a topic easy or difficult to understand			
B1. What do you consider easy or difficult about teaching this idea? (Original CoRe: Difficulties/limitations connected with teaching this idea)			
C. Learner Prior Knowledge			
C1. What are typical students' misconceptions when teaching this idea? (Original CoRe: Knowledge about students' thinking that influences your teaching of this idea)			
D. Conceptual Teaching Strategies			
D1. What effective teaching strategies would you use to teach this big idea? D2. What questions would you consider important to ask in your teaching strategy? (Original CoRe: teaching procedures)			
E. Representations			
E1. What representations would you use in your teaching strategy? (Only in adapted CoRe)			
Additional Questions not linked to a specific component			
What ways would you use to assess students' understanding (original CoRe: Specific ways of ascertaining understanding)			
What aspects of teaching and planning for this big idea would you like to reflect on? (Only in adapted CoRe)			

Appendix B: Lesson observation schedule

Observation schedule

	Big idea 1				**Big idea 2**				**Big idea 3**			
levels	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
A. Curricular Saliency												
A1. What do you intend students to learn about this idea?												
A2. Why is it important for students to know this?												
A3. What concepts need to be taught before this big idea?												
A4. What else do you know about this idea that you don't intend students to know yet?												
B. What makes a topic easy or difficult to understand												
B1. What do you consider easy or difficult about teaching this idea?												
C. Learner Prior Knowledge												
C1. What are typical students' misconceptions when teaching this idea?												
D. Conceptual Teaching Strategies												
D1. What effective teaching strategies would you use to teach this big idea?												
D2: What questions would you consider important to ask in your teaching strategy?												
E. Representations												
E1 What representations would you use in your teaching strategy?												
Additional Questions not linked to a specific component												
What ways would you use to assess students' understanding?												
What aspects of teaching and planning for this big idea would you like to reflect on?												

Appendix C: Rubric for quantifying TSPCK as captured in a CoRe.

Component prompts	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
A. Curricular saliency				
A0. How were key ideas selected?	- Key ideas are restricted to the headings in the CAPS document. - Key ideas include pre-concepts. - There is evidence of attention to proper sequencing.	- Key ideas include the headings in the CAPS document plus one or more other ideas which are sub-ordinate ideas. - There is no indication that attention was paid to proper sequencing.	- Appropriate key idea(s) other than the headings in the CAPS document are included; - There are indications that attention was paid to the sequencing of the ideas.	- Selection of key ideas reflects the conceptual logic associated with the topic, (not necessarily using the wording of headings in the CAPS document). - Proper sequencing is evident.
A1. What do you intend learners to know about each key idea?	- Key ideas are repeated/ restated without further development into sub-ordinate ideas. - Sub-ordinate ideas were copied from the CAPS. - Identified subordinate ideas are mainly inappropriate	- Key ideas are repeated with inadequate development into sub-ordinate ideas. - Important sub-ordinate ideas are omitted; however, those identified are mainly correct. - Subordinate ideas are limited to being aware of the definitions, equations, and/or terms.	- Appropriate subordinate ideas are identified and links to key ideas are shown. - The list of sub-ordinate ideas is not extensive -Subordinate ideas that account for the application of equations and definitions are identified.	- Identifies correct subordinate ideas and explains links to key ideas. - Identifies sub-ordinate ideas that focus on understanding the concepts. - Subordinate ideas constitute an exhaustive list of concepts to be taught. - There is evidence of appropriate sequencing of ideas.

Component prompts	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
A2. Why is it important for learners to know this key idea?	• The reasons provided are limited to the general benefit of education. • The key idea is restated. • The reasons provided indicate no logical link between the key/ subordinate idea(s) and its importance for key ideas that follow sequentially.	• The reasons provided exclude considerations such as scaffolding / sequential development. • Reasons include reference to the selected key and sub-ordinate ideas rather than topics that follow sequentially on the key idea.	• Reasons provided include evidence of understanding of conceptual scaffolding / sequential development.	• Reasons provided include conceptual scaffolding / sequential development of an understanding of specified subsequent topics in the subject. • Understanding of the importance of the key idea concerning other ideas in the curriculum and the learners' understanding of the world around them is evident.
A3. What concepts need to be taught before teaching this key idea?	- The pre-concepts mentioned are not appropriate for the key idea. - There is inadequate evidence of knowledge about sequencing. - Identified pre-concepts are sub-ordinate ideas of the selected key idea.	- Identified concepts refer to elementary concepts regarded as basic to the subject or topic. - Pre-concepts that are directly related to key ideas were omitted.	- Identified pre-concepts consist of those required to understand the current key idea.	- Identified pre-concepts include those needed in discussing the introductory definitions and those sequentially needed in the key ideas of the current topic (refer to expert CoRe). - Concepts from other topics having logical links with the key idea are included.

Component prompts	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
A4. What else do you know about this idea- (that you do not intend learners to know yet?)	- There is no evidence of knowledge about sequencing or scaffolding. - The placing of concepts is illogical.	- There is some evidence of knowledge about sequencing or scaffolding. - Ideas that are unlikely to be discussed at the school level are selected. - Knowledge of the curriculum is not evident.	- There is evidence of knowledge about sequencing and scaffolding of concepts. - Content knowledge is evident. - Key ideas following the current key idea are included.	- There is evidence of knowledge about logical scaffolding and sequencing of ideas in the topic and subject (refer to expert CoRe). - Selected ideas indicate strategic thinking about content. - Rich content knowledge is evident.
B. What makes the topic difficult to teach				
B1. What do you consider difficult about teaching this idea?	- Knowledge about this component is not evident. - Key ideas are rephrased or restated. - Broad topics without specifying the actual sub-concepts that are problematic are identified.	- An appropriate difficulty related to one of the key ideas is identified and formulated.	- Appropriate difficulties for two of the key ideas are identified and formulated.	- Appropriate difficulties for all three selected key ideas are identified and formulated. - The response mentions gatekeeping concepts that when not fully understood add to the difficulty of the key idea. (Refer to expert CoRe)

Component prompts	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
C. Learner prior knowledge				
C1. What are typical learners' misconceptions when teaching this idea?	- No misconceptions are identified. - Selection of inappropriate misconceptions not related to the topic. - The response reveals its misconceptions. - The response is poorly formulated	- Identifies common learner errors rather than misconceptions. (Such as a lack of elementary pre-concepts or problems with mathematical concepts) - Identifies very basic alternative ideas or difficulties that are not normally documented as misconceptions related to the topic.	- Identifies at least one misconception. - Identifies gaps in pre-concepts. - Important well-documented misconceptions that are related to the conceptual understanding of the key idea are omitted.	- Identifies and describes several misconceptions or gaps in pre-concepts. - An indication of knowledge about misconceptions and their origin is evident.

Component prompts	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
D. Conceptual Teaching Strategies				
D1. What teaching strategies would you use to teach this idea?	- A list of general strategies without indications of how they will be employed, is given. - The suggested strategies are not conceptually connected to the key idea.	- The response indicates general teaching strategies with a limited explanation of application. - There is no evidence of acknowledgement of student's prior knowledge and misconceptions. - Insufficient conceptual development - The response lacks aspects of curriculum saliency. - Use is made of macroscopic and/or symbolic representations with no linking explanatory notes. - Limited involvement of learners is evident.	- The overall strategy is workable. - At least one aspect related to curriculum saliency or sequencing is considered. - At least two different levels of representation to enforce an aspect or concept with explanatory notes are suggested. - There is evidence of encouragement of learner involvement.	- An overall excellent and creative strategy to teach the required concept is presented. - The use of macroscopic, visual, and symbolic representations to enforce the aspect(s) of a concept is given with explanatory notes. - The response considers confirmation/confrontation of student prior knowledge and/ or misconceptions and aspects related to sequencing. - The suggested strategy is a highly learner-centred lesson. - There is evidence that strategy will support conceptual understanding. - There is evidence of integration and creative interaction of other components.

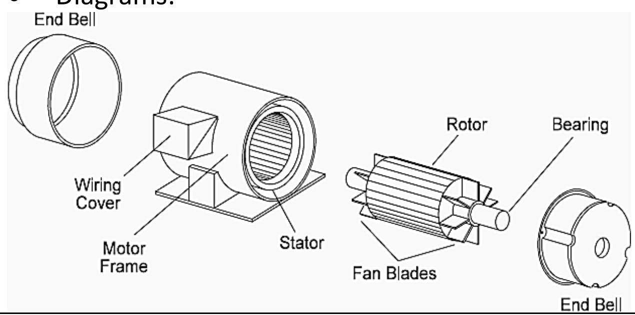
Component prompts	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
D2. What questions would you consider important to ask in your teaching strategy?	- Concepts are listed without relating them to the key idea. - There is no evidence of questions that will support conceptual understanding. - There is no evidence of the sequential development of concepts.	- Questions are basic and mostly rote learning questions are posed. - Questions do not require higher-order thinking skills. - Knowledge of sequencing towards conceptual development is not evident.	- Questions require higher-order thinking skills. - Questions lead to the constructive development of concepts. - Knowledge of sequencing is evident.	- Questions require higher-order thinking skills. - Questions lead to the constructive development of concepts. - Knowledge of sequencing is evident.
E. Representations and analogies				
E1. What representations would you use in your teaching strategy?	- The representations mentioned are vague and not specific to the key idea. - Representations are mentioned with no explanation of specific links to the concepts considered. - The suggested representations are not feasible.	- The selection of representations (visual and/or symbolic) is insufficient. - There is no evidence of how the use of the representation will lead to an increased understanding of concepts.	- An adequate selection of representations (visual and/or symbolic) sufficient to support the explanation of concepts is presented. - Some evidence is given of the use of representations to support conceptual development.	- Extensive use of representations (visual and symbolic/graphical/pictorial/diagrammatic) to enforce specific aspect(s) of concepts being developed is suggested. (Refer to expert CoRe) - Explanatory notes link the different representations to the aspect(s) of the concepts being explained.

Appendix D: Master CoRe for three-phase induction motors

Big Ideas 1 and 2	**1. The construction of a three-phase induction motor**	**2. The basic principle of operation of a three-phase induction motor**
A1. What do you intend the learners to know about this idea?	• The three main parts of a three-phase induction motor are the stator, the rotor, and the stator windings. • The stator of a three-phase induction motor is known as the stationary part of the motor which houses the stator windings. • The rotor is the revolving component of a typical squirrel-cage induction motor. It is made up of a steel lamination cylinder with aluminium or copper conductors implanted on its surface. • A three-phase set of stator windings is installed in stator iron slots. These windings can be linked in a wye (star) configuration, which rarely requires an external connection to the neutral point, or in a delta design. • The types of three-phase induction motors.	• When a three-phase supply is connected to a motor, a rotating stator field is generated automatically. • The rotating stator field cuts the metal rods of the rotor inducting a large current in them. • The induced current creates its rotor magnetic field. • The rotor magnetic field and the stator field interact with each other. A force called torque Is then generated between the two fields. • The rotor starts turning in the same direction as the rotating stator field. • As the speed of the rotor increases less current is induced in the rotor.
A2. Why is it important for students to know this?	• To identify the main parts of a three-phase induction motor. • To test a three-phase induction motor. • To use three-phase motors. • To deduce the advantages of three-phase motors compared to single-phase motors	• To explain the cause of the rotor to rotate in a motor. • To explain how torque is generated in a three-phase motor. • To link the speed of rotation to the induced current in the rotor. • To differentiate between the rotor speed and the synchronous speed.
A3. What concepts need to be taught before teaching this idea?	• The operation of a three-phase system • Star and delta connections • Identifying parts of a single-phase induction motors	• Principles of magnetic fields • Self and mutual induction • Faraday's law

(Big idea 3 follows on page 4)

Big Ideas 1 and 2	**1. The construction of a three-phase induction motor**	**2. The basic principle of operation of a three-phase induction motor**
A4. What else do you know about this idea (that you do not intend learners to know yet)?	• Losses of a three-phase induction motor. • Slip	• The speed of the rotor is inversely proportional to the current induced in the rotor, but the current induced in the rotor cannot be zero as there will be no torque produced. • How to change the direction of rotation.
B1. What do you consider difficult about teaching this idea?	• The concepts do not form part of learners' everyday lives, thus making them challenging to understand.	• The concepts are not part of the learners' everyday lives. Their knowledge of magnetic fields is confined to permanent magnets. • The operation of an induction motor is an abstract concept. • Learners find it difficult to understand how two magnetic fields moving in opposite directions cause a force.
C1. What are typical learners' misconceptions when teaching this idea?	• Learners believe the stator is the frame of the motor. • The rotor of the motor is often seen as a solid cylindrical metal.	• The current causes the rotor to rotate and not the magnetic field.
D1. What teaching strategies would you use to teach this key idea?	• Direct instruction and cooperative strategy as most of the subject is practical-based. • Use a real motor to identify the parts of the three-phase motor. • Use a cross-sectioned motor model to identify the stator windings and how they are placed in the stator. • Use a video to identify the parts and explain their uses.	• Direct instruction and cooperative learning. • Use an animated video to help explain abstract concepts.

Big Ideas 1 and 2	1. The construction of a three-phase induction motor	2. The basic principle of operation of a three-phase induction motor
D2. What questions would you consider important to ask in your teaching strategy?	• Ask what a motor is before explaining the main parts. • Before explaining the function of the stator, ask the learners what they understand about the stator of the motor. • Ask what laminations are before explaining the function of the stator. • Ask learners what are the effects of frequency on synchronous speed. • What information do we get from a motor's nameplate?	• Explain the concept of mutual induction. • How is a rotating magnetic field generated? • Ask learners why a three-phase motor is self-starting since learners know how a three-phase magnetic field is generated.
E1. What representations would you use in your teaching strategy?	• Animated video about parts of a three-phase induction motor. • Using a real motor to identify the parts. • Diagrams: 	• Since this is an abstract concept a video explaining using animations will be used to simplify the concepts.
What ways would you use to assess learners' understanding?	• Give learners a diagram for them to name the main parts of a motor and describe their functions. • Give learners an exercise on explaining the synchronous speed, rotor speed, and slip.	• Give learners an exercise in explaining the basic operation of a three-phase induction motor

Big Ideas 3	**3. Testing a three-phase induction motor**	
A1. What do you intend the learners to know about this idea?	• Perform visual inspection on a three-phase motor to identify faults. • Performing the insulation resistance test between windings • The insulation resistance test between windings and earth. • Safety when testing. • Continuity/resistance test.	
A2. Why is it important for students to know this?	• To identify faults in a three-phase induction motor and any other machine. • To interpret the results from the tests performed. • To protect people from harm that may be caused by a faulty motor. • To commission a motor.	
A3. What concepts need to be taught before teaching this idea?	• Usage of the Ohm meter and the insulation meter. • Safety when using the test equipment.	
A4. What else do you know about this idea (that you do not intend learners to know yet)?	• None	

Big Ideas 3	**3. Testing a three-phase induction motor**	
B1. What do you consider difficult about teaching this idea?	• Explaining how to interpret the reading of the resistance test and the insulation resistance test.	
C1. What are typical learners' misconceptions when teaching this idea?	• Learners usually think the insulation resistance test is the same as the resistance test. • The two tests are interpreted the same way.	
D1. What teaching strategies would you use to teach this key idea?	• Direct instruction and problem-solving strategies will be used. • Use the Ohm meter and a motor to demonstrate how the test is performed. Readings will be recorded and interpreted to improve learners' understanding. • Use the insulation resistance tester on a motor to demonstrate how the test is performed. Then the readings will be recorded and interpreted to improve learners' understanding.	
D2. What questions would you consider important to ask in your teaching strategy?	• What does an Ohm meter measure? • How is an Ohm meter connected? • How is an insulation resistance tester connected?	
E1. What representations would you use in your teaching strategy?	• A model of a three-phase induction motor will be used for testing. • Videos • Multimeter and insulation resistance tester	
What ways would you use to assess learners' understanding?	• Give learners an exercise on interpreting the results from the insulation resistance test and continuity test. • Use previous exam question papers.	

Appendix E: Data from interviews

Appendix E1: Interview 1

Big Idea 1: The construction of a three-phase induction motor
Researcher: A1. What do you intend learners to know about the construction of a three-phase motor?
Participant 1: With the construction of the three-phase motor, firstly, I need to get a link in it from the previous knowledge that they've already acquired from the previous grade, which is chapter 8. In grade 11, they take single phase motors. Now from the single-phase motors, learners have an end about definition of a single-phase motor, which is the main objectivity to convert the electrical energy into mechanical image. So in most cases, when the topic is introduced, the breakdown is on the supply. Now the single-phase motors are using single phase as a supply, and then now the operation of it is to produce mechanical by means of rotations. So now from electrical we have converted the energy into mechanical. Then basically we were talking about mostly in grade 11 the applications, the examples to say where are these single-phase motors used. Now learners are familiar about microwave, which uses single-phase as a supply, remember we supplied by 220 volts, and then washing machine is also using single-phase supply and then produces mechanical. Then when it comes to three-phase system, now the operation will be based on the Three-phase AC generation. Under the three-phase AC generation the major concern was about the generation of electricity, which first was in the form of DC, then later was converted into AC, but it becomes a problem when they introduced three-phase motors, because single-phase was not able to accommodate the supply of the of the three-phase motors. Now the introduction of three-phase motors, therefore, came with one of the advantages that the three-phase is able to do, which is self-starting. Now it means we can introduce the formation of the three-phase system, which is two construction such as the star connection and the delta connection. Then now that we have the start and the delta connection, therefore, the three-phase induction motors were able to operate under that supply. That is the introduction of the three-phase and how they came about with the advantage of self-starting. Then from there we are looking into there are construction. Now the construction with accommodate is two connection that I've already added, which is the three of the start connection and the delta connection. So now the particular connection on the terminals, if you look at the terminals, we have the terminals, we the vertical connection will represent the delta, whereas the horizontal connection of these motors will represent the start connection.

Researcher: A2. Why is it important for students to know about the things that you mentioned in the previous question, the supply of a motor, the conversion of energy, the advantages of a three-phase motor and the connection of star and delta. Why is it important for students to know this?

Participant 1: It is important because learners are expected to align the objectives of the three-phase induction motor. What is the independent objective of the three-phase motor? So now that is why it is important because now when we talk about the single-phase motors, we talk about smaller applications as compared to three-phase motors. Now the three-phase motors are the motors we are expecting them to convert or to work at a level of large amount of energy. So now for an example, let's look at the applications of the three-phase motors. Now with three-phase motors, we talk about two pumps. Now remember, when we have the pool, we need to pump the water slightly down from the ground up so that it can have a pressure, enough pressure, which is the energy we are referring to, so that it can go to far eight points where we need to get the water to. Mostly the pumps are mostly used in the windmills and the pumps and then we also have the three-phase motors, which are paid applications in the household, mostly when we have the swimming pools. So, where we have to also use the three-phase motors there to clean the pump there, or also for the jacuzzi. So now there are many points where we are using these three-phase motors. So now the main aim is for these motors to have enough energy. One of the practical examples that I like to allude to, or to refer learners to, in the event when they go to malls and then now, they are to use the escalators or they are able to use the lift. So those motors cannot be driven by the single-phase. Remember now the load to the energy that is needed to be driven by. We used the phase motors to drive those escalators to drive those lifts. So now that is why it is important for them to know, then the main purpose, because of now one must also consider that those motors at the end of the day, they can work on their home. So then now we must consider what is the main objective of having these motors and are now also in taking into consideration the protection to these motors, suggest protective devices which protect the entire system of the electricity in making sure these motors deliver accordingly.

Researcher: A3. Thank you very much. What concepts need to be taught before teaching them the construction of a three-phase motors?

Participant 1: Uh, already as I have alluded, I believe that the practical examples which lead to a real life situation where they are used or they are in contact with, but at some point you find that most of our learners were not aware, that the minute you are able to construct an example that is related to their daily life situations where they are in contact with the use of these motors, but as you find that they were not aware of the use of them. So now that alone is going to allow their interest into a topic and make them make sure that they understand, and they can also be able to can have questions going further in order to ensure that they understand the main objective of the topic is then achieved. Thank you.

Researcher: you are saying the usage of the motors is very important to teach them before we teach them about the construction?

Participant 1: Yes. Yeah. Of course, now they need to know what these motors will be used for. Yeah. What is the intended objective there, the outcome, like we are expecting them to achieve in teaching them this topic?

Researcher: A4. Next question. What else do you know about the construction of the three-phase motors that you don't intend learners to know at this point? When you've started teaching them, maybe there's something you don't want them to know at this point?

Participant 1: Yeah. Basically, it will be about the introduction of the protective devices. Okay. But now we shouldn't be focusing on them because of them is when we're talking about how they should be connected in order for them to actually the intended objective. So, for now, we have to focus on their construction, basically, where are we getting that from? So now we without therefore focused on how are they constructed. If you allow just, I will just allude on it, we talk about two major parts that constitute a motor, which are the stator part and the rotor part. Okay.

Researcher: B1. Next question there. What do you consider difficult about teaching the construction of a three-phase motor?

Participant 1: The major difficult part might be the theory part, most cases for learners to understand because the major barrier we have in teaching, the difference between the subject, myself as an educator, also learners, which is the language. The barrier is created by the language because of most of the explanation has to be put into the terminology in terms of the language that it must be used in order to articulate how these motors are constructed, how are they achieving their objective?

Researcher: C1. Next question. What are typical learners' misconceptions when teaching construction?

Participant 1: The misconception in most cases that learners, they are failing to align themselves to the terminology used, because if I were to be honest with you, even when you were to ask questions and listening to that response, you discover that the learners do have knowledge, but because of they are not comfortable with the instruction of being English, they therefore fail to express their understanding. But now, when you are to look into them, try by all means to have them on par, elevate them from your side in order for them to be able to think, answer the questions accordingly. Then, the most important thing you need to break down for them to understand, that is why now, if you introduce them, talking about the three phase motors. Therefore, you refer to them the three-phase, in this case, we regard to it as the supply, the motors will get to be there as a device that uses a supply of electricity and converted to mechanical energy. Therefore, then, when you break it down, it construct a definition that now or now they become aware and so on, now we have to know about this. So now, they then become more involved, though they are challenging, they are not comfortable to participate in classes because of the language. They have answers of their own, but they do not have a way of expressing them because of the barrier in the language, mostly because of the terminology used.

Researcher: D1. Next question is, what teaching strategies would you use to teach the construction of a motor?

Participant 1: mostly an instructional method, you just instructed them to say that, remember that the motor consists of two major parts, being a stator part and the rotor part. Now, when constructing the motor, now what are the considerations here is to consider what I have alluded as an introduction to the topic as the three-phases supply, and then now the motor would produce this mechanical rotation. Now, these two major parts are not electrically connected to each other, but the principle of operation is based in a magnetic induction. Now, if we remember now how magnetic induction is achieved, now we talk about two pair of magnets, placed opposite each other before we can begin connect. Now, let's consider them. Let's put two pair of magnets, from what they already know is, when you put them opposite each other, they repel each other or they attract each other. Now, what does that mean? It means that between these two pair of magnets, there are forces. These forces might either be the forces of interaction or the forces of repulsion. Those forces between these two magnets are therefore called the magnetic field, which is generated automatically. Now, the minute we put all introduce the rotor in the field and the rotor, and therefore we produce this rotation because of now there are electromagnetic forces that touch through and induce themselves into the rotor that are resulting in a rotation of which now is therefore then achieved because we have used the stator, which is connected to the magnetic field, to produce the magnetic field, which in turn produced the rotation of the motor.

Researcher: D2. Moving on to the next question. What questions would you consider important to ask the learners in your teaching strategy?

Participant 1: Well, what is important is for me to get to know what do they already know? What do they understand about the three-phase motor to start with? And then now what is an advantage of using a three-phase motor over a single-phase motor? and then also the another construction of the motors I would like to get from them if they know about the parts that constitutes or builds up a motor.

Researcher: E1. Moving on to the next question. What representation would you use in your teaching strategy? By representation, I'm talking about the teaching media. What do you normally use? Participant 1: Often we use textbooks to refer to them that this is what we're talking about. They see the pictures of the motor. They see the construction of the motor so that now we also mention the advantages. Also, taking into consideration the principle of operation of the motor, which is the one that I refer to as an instructional, because of it consists of the steps for a motor to operate. It has to be connected to the supply. Now, the supply to the three-phase supply. Therefore, either might be connected in a form of a star or a delta, which I will give you later when I'm doing the motor testing. Now, in this case, now, when you are interested in the principle of operation to say, now, remember, we said the motor consists of two major parts, the stator part, and the rotor part. So now, this is how it works, the stator part is the one that is connected to the AC supply. Once it's connected to the AC supply, this is what it takes place. Now, when connected to the supply, the magnetic induction is generated automatically, which produces or which induces the voltage to cut through and the rotor that produces the rotation. Then, it then achieves the principle of operation. Researcher: The last question of the construction is, what ways would you use to assess the learners? Participant 1: come again. Researcher: How do you assess the learners' understanding of construction? Participant 1: Unfortunately, or on this one, because of it's more of, it's more the construction and the principle of operation is more likely the principles, because of the principles means the guideline. There is no way you can introduce someone's understanding, but they are always giving me research for them to memorize. I can face what was of, I regard it as a technical question to them, because of it has to deal with them reading, understanding, and memorizing it, so that now they know that we're in trouble with principles. We talk about the step-by-step now. We cannot talk about the rotation of the motor when in the absence of the supply. So, now it means what we start with the supply, then it must be followed with what happens after the motor has been connected to the supply. Therefore, we talk about the step-by-step, chronological step-by-step application of the motor, how the motor operates, so that even when we assess them, I cannot be assessing them with the question that it's at the end, which is an intended objective. I must start with the basic, come with it, step up to the point when the motor objectives are achieved.
Big idea 2: The principle of operation Researcher: A1. The first question, what do you intend learners to know about the principle of operation?

Participant 1: Now, the principle of operation in most cases, like I said before, that we look at the intended objective of a three-phase motor. Therefore, if informed by what the manufacturer has to satisfy. Now, we go and look at the motor. Now, I want to link this one to the next topic that we're referring to. We link it to what we call a visual inspection of the motor. Now, one has to inspect the motor to check if that's the motor meet the requirement of a three-phase induction motor. How are you going to see that it meets the requirements? Now, we look at the specifications of the motor to say to what supply must you connect the motor. Now, what we are expecting to find, we're expecting to find on the input of the motor the three-phase as an indication of the motor. We are referring to that we are working with the three-phase motor. The minute we know that it's a three-phase motor. Then that is when we can start to talk about the principle of operation of the motor. Now, which is what it informs us that, first, the first step of the principle of operation of the motor is to connect the motor to the three-phase supply. Therefore, the motor must connect to the three-phase supply.

Researcher: A2. Next question. Why is it important for students to know this, to know about what you mentioned in the previous question, the visual inspection, the supply of the motor? Yeah.

Participant 1: What I didn't intend to inform them at the stage of the introduction of the topic was, the main objective, which was the protective devices, is for them to know that when they are working with these equipments, we must consider their safety and as the users of these equipments and also to the safety of the equipment itself. So that is why it is important for them to be on par or to understand, to be questioned about this, to understand that this is what I was working with. They must also consider advantages and the disadvantages, so that they align themselves in the safety of these devices.

Researcher: A3. Next question. What concepts need to be taught before teaching them about the principle of operation?

Participant 1: I believe that by now, it will be only the terminology of understanding from the previous topics, principles such as the mutual induction, how mutual induction is achieved. Remember, your induction is the principle, but which derive from the principle of having the self-induction, and to the point where we achieve the mutual induction. Now, once they understand that they remember the stator part of the motor consists of the field coils. Now, for one to understand how the field coils operates, we must take them back to the effect of the coils when connected to the supply. Now, they have made the coil connected to the supply. The principle such as the mutual induction principle or the self-induction principle is that when the current flows to the loop surface of the coil, now the electro-motive forces (EMF), they build up and collapse in the surface of the coil. Now, the coil we are referring to the conductor that is uninsulated. So, now, in the process of the current flowing in the loop surface of the coil, the magnetic fluxes will build up and collapse. That is the technology I was referring to. Now, this building up and collapsing causes the EMF to be induced which catch through the surface of the looped coil or the conductor. In an event where the conductor is a standalone coil, it will expand and allow the current to flow. That's the principle of self-induction. But in an event where the coils are now more than one or two, then now that's where the principle of mutual induction is then connected with, because of there will be a tendency of what is going through a primary coil can therefore be referred to to then also to flow on the secondary coil. Now, what would be the principle here? The key focus area, for example, it should be the poles. Now, we must talk about the poles. Remember, when I alluded to them, there is a north pole and south pole. Now, learners need to know as we talk about the principle of operation that three-phase motors can have multiple poles, but those poles must be in pairs. There is no way to have a single pole. Now, when we talk about a pair, we talk about the north pole and the south pole. The first two are a pair. So, it can go in the multiple of two. Then, the two poles are supposed to have that efficiency of working with one another. So, now, if we break down those poles, and then how the pole pairs works, and then now the principle of magnetic induction will then take place, and then that will put everything in order for them to understand the principle of operation.

Researcher: A4. The next question, what else do you know about this idea that you don't want learners to know yet? What else do you know about principle of operation that, at this point, you don't want learners to know yet?

Participant 1: What I need to consider now is, there is the longer the motor is connected to the supply, the motor has a tendency to develop heat. Now, the sooner the motor develops heat, now we start to talk about the losses. Now, we talk about too much current in turn from the supply, and therefore, that is when now, we need to talk about protective device that need to be put in place. Now, they are in line with the construction and in line with the object key. How the motor is being connected, how the motor is being constructed, and the testing doesn't need to be done as troubleshooting in identifying what will be the cause, what is happening in the motor by the time it develops heat and what are the causes. It's not then yet at the stage where it has to be mentioned.

Researcher: B1. Next question. What do you consider difficult about teaching the principle of operation?

Participant 1: The difficult part of teaching is the principle of operation. It is only when the learner will fail to understand the chronological application of these motors, because what it needs to be given as a jurisdiction, in this case, we need to mitigate the information to say it has to open chronologically, step-by-step. It should not be in the form of where a learner will mention the rotation of the motor before can mention the supply of the motor. That is what the really difficult part. But the minute the learners understand the principle, that the principle means that as you connect to the supply, this is the step number two, this is the step number three, the point where the motor produces rotation.

Researcher: C1. Next question. What are typical learners' misunderstanding about principle of operation?

Participant 1: The misunderstanding the learners often have actually is for them to mention the step by step. I mean, that is the only thing they are messing up in most cases. But for them, we need to understand that it must be connected to the supply and also to consider that there might be losses that will occur. And it must also consider that they are safety as well and the safety of the equipment in making sure that it is not damaged.

Researcher: D1. Next question there. What teaching strategies would you use when teaching the operation?

Participant 1: The operation actually in most cases is often interesting when you refer to them to the practical application of it, where you connect it to the supply and then it's the point where they then understand how the motor operates, the production of rotation, and all those things. Because at the end of the today, you need to also consider the efficiency of the motor. Now when you talk about the efficiency of the motor. Remember, the biggest advantage there is for them to understand that the magnetic field is generated automatically. Now, when you refer to the principle of the magnets, attracting or repelling from each other. Automatically, it is magnetic field, but then you can include the rotor, then you produce rotations. But now what do you need to understand if you check the direction the motor rotate. Now, that leads us to talk about the synchronous speed, which is the rotation of the magnetic field. And then now they use the rotational speed of the rotor, that is, and we therefore have the difference. The difference now is in the form of slip percentage. Now, the slip is in the form of when the motor rotates at full load speed. It was expected to be rotating at 100 percent efficient, but the motor is rotating perhaps 90 or 80 percent, and there is a difference of 20 percent, which was referred to as a slip percentage, which hampers the motor not to achieve 100 percent, that is expected as an efficiency of the motor.

Researcher: D2. Next question there. What questions would you consider important to ask in your teaching strategy? What questions do you normally ask when you are teaching about the operation?

Participant 1: one is to what considerations will we give to for one to operate the three-phase motor? Okay. Yes, consideration that as what should be a supply for the three-phase motor? And now when working with the three-phase supply, what are the voltage ranges of the three-phase supply? Okay.

Yes, and then what is an intended objective? which is to name the chronological step by step, principle of operation of the three-phase induction motor.

Researcher: E1. next question. What representations will you use in your teaching strategy?

Participant 1: Now, on this one I will be having in my lesson plan. I'll be my projector screen there, my laptop, and I will be referring to them to the visual pictures that they can see as we talk about those principles of operation, what I will be referring to and so on, and play some videos and just move them to understand how it happens, which we can play the video and pause the video just to check the questions, if they have any questions, just to check with them if they understand, and up to the point, linking with what has been explained already.

Researcher: The last question about the principle of operation is what ways will you assess learners' understanding?

Participant 1: we look at the cognitive levels and ask them the questions, which is for learner to understand that what will be there is a principle of the operation of the motor, which is to talk about the stator part, and then now the core, which will be now at another cognitive level, which is how does magnetic field be generated, and how it is introduced into the rotor and up to the point where the principle of operation, the entire topic is based on the principle of mutual induction, will they be able to break down that because of how we're looking at the angles at which the examiner and they might be able to ask the question. Either by means of asking them to name the concept by step-by-step principle of operation, or they can either break it down, or step by step. Now what is the purpose of the stator in the motor, or the principle that the motor is based on in order to achieve the principle of operation, therefore the learners must be able to break down those questions and putting them together. The main objective should be there to break down the cognitive levels of the knowledge to say there should be an easier type of question to say, this is what I must consider, this is what I must consider as a difficult question, and this is what I must consider as an objective, given the principle of operation.

Researcher: Okay, I heard you mention that you have to think about the examiner and what he is going to set, so does this mean maybe use a previous exam papers to test the learners?

Participant 1: Yes, because remember in every topic which we do, we do have questions such as class activities that we give at the level, addressing what we've achieved, but at the end of the day we were to integrate the questions like I'm talking about the cognitive levels. Now referring to the examiners, I'm referring to the previous year's question papers and other sources we have, but mostly the question papers I'm referring to are within 2020 to 2022 official questions papers, such as the preliminary

examination and November/ December final examination question papers, where these questions are then asked and then they give the learners an opportunity to be exposed to the types of question to expect an exam in a form of those levels that are being addressed as an easy type of question,
or as they go gradually to the point when we ask them the difficult questions and then at the end of the day entirely actually objective of the topic.

Big idea 3: Testing of a three-phase motor

Researcher: A1. First question under testing, what do you intend learners to know about this testing of a three-phase motor?

Participant 1: Now, we have a few of the motors, like I said before, that there are things we did not mention that an event where the motor can be used for too long it will develop heat. What would be the causes for a motor to overheat? Yeah. Then I'll go back to the aspect that we have to consider before we can operate the motor. Actually, the testing motor was supposed to have come first before the operation of the motor, so that we get to know that we are safeguarded as we are operating these motors. Now, under the test motor, the motor as one already alluded, which was the supply. We talked about the three-phase supply to say now it should be a three-phase supply. Now, under the three-phase supply we talk about the two connections which are the star and a delta connection. We must check if the motor is a star connection or the delta-connection. How do we see that? We said the vertical connection on the terminal. Go back to the terminal box of the connecting the motors. L1, L2 and L3 are connected to what? If it's the vertical connection on the terminal of the motor, either by opening the motor for learners to be exposed in the internal connection of the motor. We have a star connection, which is horizontal, and we have the vertical connection to the delta. It's not there, that is the three-phase supply. We check if the three-phase supply L1, L2, L3. After that, we come to check if the motor is insulated. Now, insulation, what are our intended objectives? Our intended objective under the insulation resistance test is to check the insulation resistance, check the insulation resistance between the terminal and earth, between the terminals themselves. If they are insulated, there is no way they can make contact with one another. Now, what is the main principle that guides us when doing the insulation resistance test? what is the minimum acceptable value that we are expecting to get when doing the insulation test, which is from the previous grade they have been learning about this, the one mega ohm. One mega ohm is the minimum acceptable value of which we can measure anything on a motor. It's above one mega ohm, then that's the acceptable value. And then after the insulation between the wires and the earth, we have what you call a continuity test. Now, under the continuity test, we check that now these terminals, for the example, terminal U1 is connected to terminal U2. So, now, if we want to check the resistance, what is the main objective? We just check that the other one must have the higher resistance and then the other one must have the lower resistance. Now, there the exposure of the objective that we did not mention yet at the stage is that the motor can operate on both the star and the delta. Remember, we spoke about the star and the delta connection in that the motor can be connected in a star or a delta. Now, what are the people? You just connected to a three-phase supply, which three-phase supply is mostly associated with the high-voltage. Now, the intended objective is that before, in most cases, we have a starter such as to start the motor in star and later operate the motor with delta. What is the main objective of doing that? It is for a motor to connect to start with the high-starting current. So, now, in most cases, the motor can be connected in star in order to run in delta because of the star can accommodate the high-starting current, can accommodate the self-starting. Then, the delta can deal with the high voltage because of in most cases, you can observe that delta connection doesn't have a neutral point, whether the star connection has a neutral point.

Researcher: A2. Next question. Why is it important for students to know about the star and the delta connection, the insulation resistance test you spoke about and the continuity test?

Participant 1: The delta connection is for learners to know that most machine in household environment and they must know one of the questions such as why must you use that to start a motor. Remember, the star has an internal point and now it's a domestic application or in industry. So, there is a star connection brings about the balance in the system of connection, whereas the delta connection doesn't have a neutral point. So, now, which it deals mostly with the high voltages. Then, now, for the insulation resistance, it is to make sure that there is no connection. To insulate means that to isolate a wire from another, so that it doesn't make a short circuit, it protects the motors and then the continuity ensures that the current flow will be a correct channel to the expected exit terminal, such as if it's U1 for example, the output would be U2. If it's V1, the output would be V2. Just like that, that's when now the continuity allows us to say this wire and also communicate in an event where, because in most cases we talk about the colour coding, such as your red phase, yellow, and the blue one. So, now, if you communicate moving to the next person or to work with the motor, one might not be the person who constructed the motor, who can understand that whoever constructed the motor has used this phase as, the continuity or the flow or the chronological connection of it, so that one can understand and so can interpret and can also be able to can troubleshoot in an event the motor has a problem or damage.

Researcher: A3. Next question, what concepts need to be taught before teaching them testing of a three-phase mode?

Participant 1: The major concept is safety. For them to understand safety. Talk about protecting devices, talk about the safety of the equipment, we talk about the safety of the user of the equipment.

Researcher: A4. Next question, what else do you know about the testing of a three-phase model that you don't intend learners to know yet?

Participant 1: The only thing that we, we haven't arrived at yet is the issue of the starters, which of them I refer to not the general knowledge people. It means that there are practical applications to say that the starters gives instruction to motors on how to operate when connected to the supply.

Researcher: Practical applications of status.

Participant 1: Yes.

Researcher: B1. Right, the next question, what do you consider difficult about teaching learners testing of a three-phase motors?

Participant 1: Well, the difficult thing about the testing of a three-phase motor is that the learners do not know how to use the meters, they do not know which meter to select when conducting a certain test. For example, if you test for continuity, they do not know which meter they must use, and which scale they must select. When measuring the insulation resistance, which meter must they use, and which scale they must select as well. So that is what I consider a challenge for them, mostly. But remember, taking into consideration that using an insulation test, that it is a dangerous instrument, which they therefore, that is why I say the key words, or the key points there must be safety.

Researcher: C1. Um, next question. what are typical learners' misunderstanding, or misconceptions when teaching testing?

Participant 1: Uh, the real misconception that they make is when they do not understand the terminals or they don't understand how to troubleshoot the terminals, and then how to track them, and also the recording of the findings. For example, you are doing continuity, they will just write numbers, if they do understand, they will just write numbers. Not taking into consideration that they must use the scale; they must use the prefix. You can just find that the insulation tests that have prefixes as mega or giga ohms, which, at the end of the day are the intended to inform the objectives of the testing. We used to check if the test, it doesn't meet the minimum acceptable conditions, and so on, and then now, what are the guidelines to inform, uh, whoever was testing the motor, if you got a meter requirement?

Researcher: D1. Um, what the teaching strategies would you use when teaching the testing of the motor?

Participant 1: The testing of the motors will use the panels for three-phase motors. We use the motors, we expose to them, we take the three-phase motor, so we put here, we open it, show them the terminals, we show them how this must be done, and then in a visual aids, such as videos that are in place, such as found in YouTube, expose to them, we play those videos for them, so that they can see what is intended about the motors.

Researcher: D2. Uh, next question, uh, what questions will you consider important to ask when teaching about testing?

Participant 1: When teaching of testing, remember, as I said, the cognitive levels, which are the cognitive levels, uh, which will be to which instrument should be selected to conduct a setting test? Then the lower, uh, the lower order question is, are the types of tests to be conducted? What types of tests are typically in a motor? And what instrument must be used to conduct those tests? And what are the intended objectives of connecting these tests?

Researcher: E1. Uh, next question, um, what representations will you use in your teaching strategy?

Participant 1: Uh, the, uh, the, the media used in this, uh, will be to take motors, physical motors, you put them there, give them screwdrivers, open them, show them the terminals, uh, play the videos so that they can, uh, be exposed or give them meters to do it practically, actually this one, it took most likely interest in when done practically done explaining the explaining. I will refer to it as a guideline of what is intended as we are going to do the motors practically. Because I consider introducing the testing of the motors as introducing them to, to the practically.

Researcher: Our last question, uh, what ways will you use to assess the learners' understanding?

Participant 1: Uh, the learners understanding, uh, will be then assessed by, I mean, that's for them to understand the main objectives of why are we doing testing, why is it acceptable, and what recording should be given. Because they did this one question paper that I liked in 2020 during the covid time. I think for the June exam, where they do the PAT paper, they call it a PAT paper. So on that PAT paper, the learners were exposed to the question where what are the expected tests, where you are conducting tests in the motor, and also the recordings to indicate the infinity for a continuity to indicate the resistance for insulation resistance, then, then also to take into consideration the minimum acceptance, so that now those are a form of assessment that I will use to assess them.

Appendix E2: Interview 2

Big idea 1: Construction of a three-phase induction motor

Researcher: A1. what do you intend learners to know about the construction of a three-phase motor?

Participant 2: Basically, they should know that a motor is a machine and in most of the case, when you tell learners about a machine, they first start thinking of an engine. And it's always advisable that you show them what type of a machine are you talking about? So, it's always important to have a three-phase motor ready in class so that they can see it, don't only imagine it, but see it. So, you tell them that it's a machine and sometimes they might think of something very huge. Then if you have it, it's good because they'll change their mind and see, okay, no, no, no, no, a three-phase machine can it take any size, can be the same size of a single-phase motor. They don't differ that much, they are literally the same, they have the same size, the same shape, and the construction is the same. I'm talking about the single-phase and the three-phase motor. So how are they going to know all the differences? This is where you must explain about the windings. This is where you must explain about the operation or the uses of the single-phase and the three-phase motor. This is where you must talk about the advantages and the different advantages of both single-phase and three-phase motor.

Researcher: A2. Move on to the next question. Why is it important for learners to know about what we have mentioned in the previous question, the different sizes, the windings, for you to show them the motor. Why is it important for students to know this?

Participant 2: It is very important for them to know like the windings, the motor cannot operate with our windings. Remember, we have two types of windings. We have the main windings or the windings on the frame. And then we have the winding on the rotor. The windings on the frame are called the stator windings, which are not moving. And then the windings on the rotor are the ones that are moving. In other words, this is the rotating part of the motor. So, it is always important for them to understand that the operation, the rotation will happen inside it, and how is it going to happen? That is when we talk about the operation.

Researcher: A3. What concepts need to be taught before teaching about construction of a motor? Like prior knowledge, what is it that need to be taught before?

Participant 2: Yeah, number one, it should be the frame, and then the frame being the housing of the motor. And then we come to the internal part of the motor, where we talk about the laminated iron core inside the motor, were we talk about the shaft, where we talk about the movement of the current inside the motor, and then the other thing that they should know, it's the law of magnetism, we have Lenz's law, we have Faraday's law, we have yes, I think, I think that's that.

Researcher: A4. The next question, what else do you know about the construction of a motor that we do not intend learners to know yet?

Participant 2: The construction? Yes, that should not know, or they should know.

Researcher: Now, something you do not intend learners to know yet, maybe we'll teach them at the later stage, or if there is nothing, there is nothing still, you just need to teach them or everything about the construction.

Participant 2: You should teach them about the construction of it, or the composition of the motor itself,

everything must be taught. I mean, why should you leave something out? Everything must be taught, so that they know it holistically. They should know how does it look, what happens, how does it operate, and the advantages and disadvantages of whatever the construction of it.

Researcher: Oh, thank you very much then. So, basically, you must, there's nothing that we are going to teach them at the later stage about construction, you teach them everything under construction.

Participant 2: Yeah, I remember, sometimes you cannot, you cannot start teaching motors, Three-phase motors, before starting with single-phase motors. So, by teaching single-phase motors, you touch everything, because both the motors are the same. So, everything must be touched, everything must be taught.

Researcher: thank you very much. I will add your response to what concepts need to be taught before teaching this idea. You spoke about teaching them single-phase motors there. Yes. Thank you.

Participant 2: Ah, principle of magnetism must be included also.

Researcher: B1. The next question, what do you consider difficult about teaching the construction of a three-phase motor?

Participant 2: You know what, with a construction, I don't think there's anything difficult except the windings. In most of the cases, when we talk about windings, they don't see them. Yeah. You just see something very closed, something covered when I say closed, I say something covered. When I talk about the rotor of the machine, we need to be covered. You'll never see the windings. So, why not be expecting to see those wires. You will never see those windings. It is just covered nicely covered. And then they will tell you that we have, let's say, three windings. And then you'll be expecting to see three windings where you could count that this is the first winding, the second winding, third winding. Yeah. Unfortunately, you cannot see that.

Researcher: C1. Next question, what are typical learner misconceptions when teaching about the construction?

Participant 2: As I said, they will be thinking of an engine of a car, and they'll be thinking of something very big. Okay. Something very big. No, no, no, no, we expect any size. From motors we expect any size.

Researcher: D1. Next question, what teaching structure would you use to teach the construction? teaching strategies you use when you teach construction.

Participant 2: See, most of the cases is advisable to have a model. Okay. You have a sample, you put a sample here, either a picture or the model itself. Okay. If you have either of the two where you model, let's say you have a model that is cut to show the inner parts of the motor. Yeah. And then where they can see the bearings, where they can see the shafts. It's always advisable to have such things so that learners cannot just imagine what you're talking about. Let them have it. Let them see it. It's always better. And then sometimes when you talk about rotation, yeah. I mean, I mean, the rotor doesn't touch the windings of the stator inside. There's a gap in between. And if you have a model that shows that gap, it becomes better, especially when you come and talk about the operation.

Researcher: D2. The next question. What questions will you consider important to ask in a teaching strategy? Now, what questions do you normally ask when you teach learners about construction?

Participant 2: In most of the cases, I would give them, let's say, the model itself or a picture of the model itself. And then I would say the name, all the parts that you see. Okay. And then they would name, sometimes they will tell you of brushes, sometimes they will tell you of the commutator. And unfortunately, you don't have that in three-phase motors. Yes. So, the naming of the parts of the model is always a good question to ask learners.

Researcher: E1. Next question. What representations will you use in a teaching strategy? By representation, I'm talking about teaching media, you know.

Participant 2: Teaching media in most of the cases, you must have, let's say, a laptop. Okay. And you must be having either, if you don't have a smart board as in, what do they call them? You have a small TV in front of them. You must have, what do you call it again? the overhead project, all right, projector. And these learners can see what you're talking about.

Researcher: Okay. So, what, how do you use the, the TV and overhead projector?

Participant 2: Remember, the TV either you can connect it to a laptop, or you can use the USB. Where you have your notes, your pictures of the motor from the USB.

Researcher: The last question about construction is, what ways would you use to assess learners' understanding?

Participant 2: Uh, number one, uh, you can say name all the parts of of the motor. Number two, give them different types of motors that shows the windings. And ask which one is either DC or AC machine or three-phase machine. And then you can have different types of the rotors where one rotor can have a commutator and the other doesn't have a commutator. And then you ask which one is the rotors for a single-phase machine. And then you can have different sizes of the rotors. And ask which one here is for a three-phase.
Big idea 2: The principle of operation of a three-phase motor Researcher: A1. Now, uh, what do you intend learners to know about the principle of operation? Participant 2: Number one, understand the laws about magnetism. Okay. Number two, understand the induction. When we talk about induction, how is EMF induced in the coil? Okay. What propels, what is moving inside the motor? Researcher: A2. the next question. Um, why is it important for students to know about the magnetism, the induction, and the EMF induced that you mentioned? Participant 2: Uh, remember, if EMF is induced in a coil, current is going to start moving. When current starts moving, uh, magnetic field is produced. And then, uh, that magnetic field, that is the one that causes the rotation of the rotor. But then, remember, we have the windings of the stator and the winding of the rotor. Now, the EMF starts from the stator. The rotor doesn't have any EMF because the rotor is not connected directly to the supply. So, the supply is from the stator. And then how is the rotor, how is it going to rotate? This is where the magnetic field comes in. This is where induction of the, the, the EMF from the stator to the, the rotor comes in. This is where opposite magnetic field, uh, the MMF is going to force that rotation. Researcher: A3. Thank you. Um, what, uh, concepts need to be taught before teaching, uh, about the principle of operation? Participant 2: Magnetic field, laws of magnetism, induction. Yeah. Yeah. Basically, that's it. Researcher: A4. Uh, next question. Uh, what else do you know about, uh, the principle of operation that you don't intend learners to know yet at this point? Participant 2: Nothing. Okay. Please definitely should know everything and understand everything about magnetism, about induction, about, uh, the movement of, uh, magnetism inside. Researcher: B1. Uh, next question. Uh, what do you consider difficult about teaching the principle of operation? Participant 2: How does the rotor when it is not connected to any supply rotate? Yeah. That is very difficult because in most of the cases, learners don't understand if they didn't understand the principle

of magnetism and induction. How current is induced, how magnetic field is produced, then it's the problem. And it is going to be difficult for them to understand the induction of EMF through the stator. Remember the stator it's totally not connected to the supply. So, it becomes a challenge in most of the cases that, the rotation, how is it going to move? How is the rotor going to move?

Researcher: C1. Um, next question there. Uh, what are typical learners' misconceptions when teaching about the principle of operation?

Participant 2: That the rotor must be connected to the supply. When you, you switch your plug on, uh, you press your stat button. Then, then the rotor will start rotating because it's connected to the supply. When, when it is totally not connected.

Researcher: D1. Um, next question there. Uh, what teaching strategies do you use when teaching the principle of operation?

Participant 2: Uh, in most of the cases, if you have the bar magnet, and then having the iron filings, and then sprinkling them on top of the paper when you have the bar magnet under the paper, that they can see that there's a field, there's a field around the bar magnet. So that, that helps, that it helps much because they can see as long as they understand that there's a field, as soon as current stat moving, even in a conductor, then this field is created around the, the conductor, then it becomes better.

Researcher: D2. on my next question there, what questions do you consider important to ask when teaching about the principle of operation?

Participant 2: Number one, what is holding the road to not to touch the windings of the stator? and then name or give the law of magnetism. There are a few of them, uh, so I don't remember them now.

Researcher: E1. it's okay. Uh, if at the end if you remember them, it's fine. We can come back and add them. Okay. Uh, the next question, um, what representation would you use in a teaching strategy? Teaching media again for now we're looking at the principle of operation.

Participant 2: Okay. In most of the cases, YouTube helps. Okay. Because, uh, to be having those pictures, you know, uh, where they try to show the, the movement of, uh, the magnetic field. Okay. Between, between the, uh, the rotor and the stator, opposing one another so that, uh, there can be that force pushing the rotor, so that it starts moving.

Researcher: Uh, what ways would you use to assess learners understanding? What, uh, what ways would you use to assess learners understanding? Like assessment, when it comes to three-phase, uh, working principle of operation of a three phase motors.

Participant 2: Uh, you know, if, if they can understand the, uh, the construction of, uh, uh, the windings of both the state and the rotor, and then understand the effects of the movement of magnetism. Okay.

Between both, both the stator and the rotor. Yeah. Uh, how do they affect each other? How do they push each other to rotate? Then I think I better understand will occur.

Researcher: Okay. Okay. So, do you give learners, uh, class activities or home activities?

Participant 2: Class activities, yes, in most of the cases, in the form of question papers, in the form of mini tests. Yeah, basically that's that. Okay.

Big idea 3: The testing of a three-phase motor

Researcher: A1. Um, first question. Uh, what do you intend learners to know about, uh, the testing of a three phase motor?

Participant 2: Before you can connect the motor. The first thing that you should do is to test. Okay. And then we have two types of tests. We have the physical one or the mechanical. We have the electrical, uh, testing. The physical one or the mechanical one is to, you know, observe, look at the, the motor. Touch it. Check all the components. Of course, you're going to see the outside in most of the cases. Check whether there are no broken fins there. There are no broke, parts, any parts, they are no broken fans. Uh, if you're satisfied, there's not nothing broken. And then the physical part is okay. Uh, on the electrical, you, you check whether the terminal box is okay. Then you can take the insulation tester or mega to check the windings, you check for the insulation. You check for insulation resistance. You check for continuity. If you are satisfied with all that, then the machine will be ready for you to use.

Researcher: A2. Um, next question here. Why is it important for students to know about their testing before connecting the mechanical test, the electrical test that you just mentioned?

Participant 2: It is always important. Let's say you get a machine. Hmm. Then what you do, you just connect without checking all those things. What if there's a fault? Then that machine will be a danger to you. And, uh, wherever you'll be using it. So, it is always important for the safety of the user. And the other component.

Researcher: A3. Uh, next question. Uh, what concepts need to be taught before teaching about the mechanical test and the electrical test that you mentioned?

Participant 2: Safety. It is very important. Remember, these are electrical machines and with electricity safety, it's number one on the list. Find out how safe the machine is. And then that's the first initial point. That's where it should start.

Researcher: A4. Um, what else do you know about the testing of a three-phase motor that you don't learners to know yet at this point?

Participant 2: None. None. Everything must be taught.

Researcher: B1. What do you consider difficult about teaching, uh, testing of a three-phase motor?

Participant 2: Remember when you test, let's say you test a three-phase motor. And then you must first check on the name plate. You check the voltages, you check the current and then when you test for insulation and resistance, all the time, you must double your voltage on the meter, on the mega. That's the first thing that, uh, learners should know. And, uh, when you go check for your resistance, your continue to actually, your meter should always be on, on the resistance scale. So, in most of the cases is difficult because learners don't consider such things. They just on to test and nothing else without actually taking the values that measure it.

Researcher: C1. Uh, let's move on. What are typical learner misconceptions about testing at the three-phase motor?

Participant 2: the windings, in actual fact, they would only want to check or test for continuity, not insulation resistance and not insulation resistance between windings, not insulation resistance between the windings and earth. And then they should know about those different coils, windings, like, uh, we have W, we have U, and then we have V. So, they should know all those, those different, and they should know what is insulation resistance, when you talk about insulation resistance, what are you talking about? When you talk about continuity, and when you talk about insulation resistance between windings and earth. Where does earth fit in, and then how do you test for earth on the motor?

Researcher: Do, do your learners know the difference between the continuity, uh, test and the insulation resistance test?

Participant 2: Yes. You tell them, especially, it is so tricky because, uh, remember the windings of the motor, if you look at them, they're just laying on top of each other. And then when you talk about insulation, it is always difficult. They don't understand how is this thing insulated. No, this is where you should tell them that, uh, the shiny part that they see on the windings, that's basically the insulation.

Researcher: D1. Uh, what teaching strategies, uh, do you use to teach about the testing?

Participant 2: You're talking about media.

Researcher: And, uh, yeah, teaching strategies include media in, in the, I got strategies, media or method of teaching.

Participant 2: All right. I'll be having a laptop. I'll be having, uh, a smart board. I'll be having a meter. They should know and see. Remember, we are using a megger here, insulation resistance tester. Yeah. They should see the difference between insulation tester and multimeter. Because you're not to use a multimeter to, uh, test for insulation resistance. Because, uh, multimeter doesn't have all those capabilities for insulation resistance. So those are the things that I basically use.

Researcher: D2. Uh, next, uh, question, uh, what do you, or what questions would you consider important to ask in your teaching strategy?

Participant 2: Number one, I would say if you're testing for insulation resistance, what scale should you choose on the meter? Okay. If you're, if you are testing for, for continuity, what scale would you choose on the meter? And then what type of, uh, meter are you going to use when you want to test for insulation resistance on a three-phase motor?

Researcher: E1. Um, next question. Uh, what teaching media do you normally use when teaching about the testing of a three-phase motor?

Participant 2: I would use a laptop. I would use a smart board. I would use, I would use insulation resistance tester. Yes, which is called megger.

Researcher: what do you use for testing continuity?

Participant 2: Continuity. I will still use mega specifically when we're talking about a three-phase motor. Remember a mega has all those facilities and the advantage of using it is that you can go as high as 1000 volts.

Researcher: Uh, the last question, uh, what ways will you use to assess the learners understanding?

Participant 2: Number one, uh, give them class activities. Uh, give them homework, uh, test at the end.

Appendix E3: Interview 3

Big idea 1: The construction of a three-phase motor

Researcher: A1. Now, the first question, what do you intend learners to know about the construction of a three-phase motor?

Participant 3: Repeat your question, okay?

Researcher: What do you intend learners to know? Like, when you teach construction, what is it that you normally firstly prepare, like the objectives when you talk about construction?

Participant 3: According to me, we need to understand, conceptualize the topic on its own first, conceptualise the topic. And then while you are conceptualising, you will remind them of the topic based on magnetism, as point number one, and then from there is then maybe we can start to dwell in with the construction of the motor. Because as we know that we've got different types of these motors, we've got the squirrel cage based on induction. That is when now we emphasize based on induction. That's the principle of magnetism. Now the main aim, before we go to the operation, they must just know basically for the motor to operate, or for anything that has to have motion, especially when it is too inductive, they must know that the magnetism is important. So, we need to know the basic principle of magnetism.

Researcher: A2. Now, the next question, why is it important for students to learn about the magnetism, to learn about the different types of motors and induction, the things you mentioned, why is it important for them to learn about that?

Participant 3: Basically, according to this experiment from professor Oersted, when they say current carrying conductor, magnetic fields have been created. That is where now the key point starts, so that they need to understand that whenever there is a flow of current in a conductor, magnetic fields have been created. Now, that is why I say they need to understand the foundation first, before we can come to the motor itself, because coming to the construction of the motor, we know that they are going to be wires, whereby these wires are carrying current to flow, and that current flow, it creates, or it creates the magnetic field. So, if the child can miss that foundation, it is not going to be able to understand the construction and the operations of the magnetism.

Researcher: A3. Next question, what concepts need to be taught before teaching the learners about the different types of motors? What needs to be taught before teaching them about the things you mentioned, the construction, the types of motors, and your induction, magnetism, what does that learner need to know first before that?

Participant 3: Yeah, as I say, they must start from the known to the unknown, they need to know about the magnetism, properties of the magnetism, how do they behave? And then from there is then you can start to explain the construction of this motor. Maybe a plane, you take it from just an ordinary motor, yeah, we need to understand what type of motor is this. Let's say, for an example, just take a pure DC motor and explain what is happening inside. Just a simple motor, maybe a toy motor whereby we've got a magnet inside and we've got a coil that is running between the magnetics right now, we tend to explain that now, when we go to bigger motors, we are going to create these magnets, but in smaller motors, we've got those permanent magnets that will try to make the rotor to rotate or the armature to rotate. Now, hence now they need to understand the properties of the magnetic field, how it's been created and why it's been created.

Researcher: A4. Next question. What else do you know about the construction of a three-phase motor that you don't intend to learners to know at this moment?

Participant 3: There's nothing to hide. Nothing to hide, learners much more everything, pertaining to the construction of a motor.

Researcher: B1. Next question. What do you consider difficult about teaching about construction? Is there anything difficult about teaching construction?

Participant 3: Because our learners, they are not that much dynamic because there are some instances, they don't take things seriously, but if you teach them with a thing that they can see and it must be operational, that is one thing that you need to have for them to be able to understand some of the things you need to have your teaching aids and be able to interpret whatever that you see in the teaching aids or explain it, try to dismantle it and explain it to each and every component that is the function of the component and how does it aid if you apply the source of supply to it.

Researcher: C1. Next question. What are typical learning misconceptions when teaching about this idea? What is typical misconception about construction of a motor?

Participant 3: They think if you teach them about this motor, it's just for leisure, not knowing where do we operate, where do we use them in operational situations, yeah, because one might ask you, why do we have to learn motors, but we say we are doing electrical, that's what I'm trying to say.

Researcher: D1. what teaching strategy do you normally use when teaching the construction?

Participant 3: the teaching strategy that is best is demonstration and narrative.

Researcher: D2. what questions do you consider important to ask when teaching learners about construction?

Participant 3: you can ask them about the operation. To be able to pinpoint different parts and know how to explain them. How to find the information of the motor (nameplate). And they must know the purpose or the function of a motor. Researcher: E1. next question, what representations would you use in your teaching strategy? representation is the teaching media. That's another name for teaching media. Participant 3: now as we do have physical motors, As a media, sometimes we do have these videos from YouTube as a reference, because those ones we use them as visual aids in anyway so that they might see what is happening. Researcher: Next question. What ways will you assess learners' understanding? How do you normally assess them? Participant 3: It can be the first one, I prefer self-assessment. Then peer assessment. Then after that is then I can start to give them an official test where I'm going to assess them on my own. That is teacher assessment. But preferably I like it as peer assessment because that is where they are able to discuss some other points.
Big idea 2: The principle of operation of a three-phase motor Researcher: A1. Now, first question. What do you intend learners to know about the principle of operation of a three-phase induction motor? Participant 3: First of all, they must know the motor in itself is too inductive. They know the principle, why do we say induction motor? First of all, they will be able to define it. So that simply means this induction motor you can link it with the operation of a transform. You know that in this motor there are no physical connection. Only does apply and it is a brushless motor. That is not the material in operation. Now what is happening inside, hence I'm trying to link it with the operation of a transform. So that basically they must know. So, there's no physical connection between the rotor and the field windings. Researcher: A2. The next question then. Why is it important for learners to know about the induction and you linking the induction motor with a transformer? And why do they need to know that there is no connection between the roto and the windings? Participant 3: I don't know when I understand that question clearly. Researcher: I can rephrase it. Why do learners need to know about, what do you call it, the principle of operation? Why is it important for them to know about that? Participant 3: They need to know the basic operation. How does that thing operates basically? Because you cannot just learn a thing and yet at the end of the day you cannot explain what is happening inside.

So that you need to know how does it operates. Hence now, as I've already mentioned, they need to understand that this is the thing. It is too inductive. Hence, it is basically the operation. It is basically based on the operation of a transformer. So, they need to know the operation. You cannot just drive a car and yet you buy a car and yet you cannot drive it.

Researcher: another way to ask the question is, is it important for learners to know about the operation maybe for future use or something? Do they have to use it in industry? Do they have to use it elsewhere?

Participant 3: Because hence, sometimes you get those questions where these motors are applicable. Yeah. You need to be specific. You tell them some have been used in hoists, in cranes, depending on what you want to do with the motor.

Researcher: A3. All right. Thank you very much there. Now, what concepts need to be taught before teaching them about the operation of the motor? What do they need to know first before they learn about the operation?

Participant 3: They must know different parts of the motor. And the behaviour of those parts of the motor, how do they behave? And because it's a three-phase motor, we need to explain why is it a three-phase motor.

Researcher: A4. Next question. What else do you know about the principle of operation that you don't intend learners to know at this point?

Participant 3: I mean, since you have told them about the principle of operation, I mean, why hiding some of the information?

Researcher: B1. Next question. What do you consider difficult about teaching the principle of operation?

Participant 3: In this instance, kids are not able to interpret the technical language. And it is difficult for them sometimes to express themselves, technically so. And in some instances, they are not exposed to these things. They only see them here.

Researcher: C1. What are typical learners' misconceptions about the principle of operation?

Participant 3: In that case, what frustrates them, especially when you explain that this thing, it is too inductive. Because there's no physical connection. Because they want to see a connection. Because as you see, current carrying conductor and there is a magnetic field, but now in this one, they become confused and frustrated. What makes the rotor to rotate because there's no connection? As we know from the previous motors that we do have brushes and there is a current flowing through the brushes by the commutators and all the windings that form the amateur to rotate. But now in this one, it becomes now, they become sceptical now. What is the cause? What makes it to rotate? But there's no connection. We only supply the field windings, but there's a rotation. But then, that's what makes them to be sceptical about this.

Researcher: D1. What teaching strategies do you normally use when you teach principle of operation?

Participant 3: The strategies that I use, I just start it from grade 10, just to recall. As a revision, trying to explain electromagnet, and the inductor as an electromagnet, putting the iron core for strengthening of magnetic field. You bring that to your back, then you put it into application. So that they must see that magnetism is very important.

Researcher: Would you say the strategy is still the narrative method?

Participant 3: Yeah, it's a narrative method. And you make them aware. Recalling what they already know. Now we put it into application.

Researcher: D2. So, we are on to the next question. What questions do you consider it important when you are teaching the principle of operation?

Participant 3: you must consider the effect of why and how. And what is happening? Actually, we are able to explain why. That is the how part and the why part.

Researcher: E1. Um, what representations would you normally use in a teaching strategy? Uh, teaching media. What media do you normally use?

Participant 3: You have, uh, overhead project. Using the PC. For now, so far, and the panels that we are having. For demonstration purposes, especially when we connect.

Researcher: And the last question about this, what ways would you assess learners' understanding? How do you normally assess learners on principle of operation?

Participant 3: Basically, you simply phrase the question. Theoretically so. Then they explain it. Doing the writing. Because sometimes even if you can just ask them verbally so, they can just explain, but they are going to miss some other points.

Researcher: Do you sometimes use maybe like a previous exam question papers for this?

Participant 3: We do. That's part of the vision.

Researcher: By the way, if you feel like you do not explain any question properly, we can go back a bit and then we will go through it again.

Big idea 3: Testing of a three-phase motor

Researcher: A1. Our first question. What do you intend learners to know about the testing of a three-phase motor?

Participant 3: I can say before you can say they must test a motor they need to have a theoretical background first. Theoretical background in a sense of information on how to conduct those tests. Thereafter is then now what they have discovered from theory, they are going to do it in application. And they must get it according to what the book says. When testing the movie. Because I've got one print out here that explains exactly what they must do before they can do the testing of motors and so forth. You tell them step by step what they must do. Then from that, that is what I'm expecting when they go there. Because we know that if they can miss one of the tests with the motor and it's not carried accordingly. We know we have got a problem.

Researcher: Can you name the tests that we are talking about? That learners have to carry out.

Participant 3: the testing of windings as an example. Testing of earth. Testing of earth to windings.

Researcher: A2. The next question. Why is it important for learners to know about the theoretical background on how to conduct the test? Why is it important for learners to know the windings test? The earth testing and earth to windings test. Basically, why is it important for learners to know those tests you mentioned?

Participant 3: It's for protection. It's for protection. And to apply the knowledge as the book says. Because now here, we don't have to go left, or we don't have to go left or right. You do things according to the book.

Researcher: A3. The next question. What concepts need to be taught before teaching learners about testing?

Participant 3: Different types of instruments. You know the function of each instrument. Where do we use it? How do we use it? So that they must be able to know which instrument is used where. How to use it. Let's say maybe for an example, you bring them with a tongue tester. they must know how to use it.

Researcher: Specifically for testing a motor, which instruments do you normally use?

Participant 3: megger. Use a megger.

Researcher: A4. What else do you know about this idea or what else do you know about testing of a three-phase motor that you don't intend learners to know yet?

Participant 3: I don't have any. All what we are doing is according to the book.

Researcher: B1. What do you consider difficult about teaching testing of a motor?

Participant 3: Our kids don't take safety serious. Especially when using the megger. They don't take it serious. Because I had an incident one time, I gave them instructions. You must test it. Then the other one had to shock a learner with the megger. Hence now I say safety it's priority number one. Especially when using Whatever the instrument that you are using.

Researcher: C1. What are typical learners' misconceptions when you teach them about testing?

Participant 3: They just think maybe testing you are just doing it for the sake of doing it. As if now there's no purpose for doing testing. That is what's just in their mind. Why do we test? This thing is from the factory. Sometimes this thing can have factory faults. You cannot just take it and fit it in, you must test it before

Researcher: D1. Next question. What teaching strategies would you normally use when teaching about testing?

Participant 3: Demonstration. Must first demonstrate. Put more emphasis on the do's and the don'ts.

Researcher: D2. The next question is what questions would you consider important to ask when teaching about testing? What questions do you normally ask?

Participant 3: How and why? Why do we do tests? And how do we carry out tests? And they must explain what is the importance.

Researcher: E1. Thank you. What representations do you normally use in a teaching strategy? Teaching media. What do you normally use there when you teach learners about testing?

Participant 3: We are using physical equipment now. Physical equipment. We do have a motor which is standing right for them. Not connected on the source. And then. And various types of instruments that you would be multimeter in the megger too.

Researcher: And what ways do you normally assess learners understanding?

Participant 3: You do assess them. I must do it one by one. That is individual.

Researcher: So, they perform the test individually?

Participant 3: Yes, they do it individually.

Appendix E4: Interview 4

Big idea 1: the construction of a motor

Researcher: A1. The first question under construction is what do you intend learners to know about the construction?

Participant 4: As these learners are coming from grade 11 what they know is only a single-phase motor. And with a single-phase motor they do know that it has got some other parts which are called like capacitors for instance. Now introducing them to a three-phase motor they must know that with a three-phase motor we no longer have capacitors in a three-phase motor because a three-phase motor is self-starting. It does not need any other assistance like a single-phase motor. A three-phase motor has got different parts as compared to a single-phase motor but of course some of the parts will be similar and then I will be showing them all the different parts that are available in a three-phase motor and then what they should know in that particular motor is how those parts are interacting with each other to make that motor to be complete in terms of the operation.

Researcher: A2. Why is it important for students to know about the construction?

Participant 4: Well, we are building learners who must be skilful because those learners need to know as they are going out to industry that in a motor we have so many parts of the side of the parts and if one of those parts is not working according to the requirement or according to expectations then they should know what that particular thing is, the name of the part and what its purpose is exactly in that particular motor so that fault finding should become easy for them in terms of locating where the fault is or if an error arises.

Researcher: A3. What concepts need to be taught before teaching about construction?

Participant 4: The concepts that have to be taught before construction? Yes. It is actually the purpose why we should use motors. Yeah, the application actually. Why is there a need of motors? I think that is what is important there.

Researcher: A4. let's move on to the next question. What else do you know about the construction that you don't intend learners to know yet? Something you don't want learners to know now. Maybe at the latest date you will teach them.

Participant 4: What I don't want learners to know at the beginning is the actual interaction with regard to magnetism, because it is a bit confusing, and it is imaginary so if you talk about an imaginary thing learners will just look at it like that and they will fail to really get what they are saying exactly.

Researcher: B1. Still under construction. What do you consider difficult about teaching construction? By the way, you can refer to the first question where we spoke about the things you intend learners to know. I believe you said you want learners and to know about three-phase motors that they have no capacitors, they are self-starting and so on. So, you can refer to that to answer this question.

Participant 4: The easy thing in this is to show them the parts because we do have motors in the workshop, in a class environment. So, showing them the paths is the easiest thing and the difficult thing is now how those paths interact in creating the torque that is caused by the magnetic field. Reason is as I gave before then, it is imaginary so that is very difficult. Even if you use videos, it will still not sink well.

Researcher: C1. What are the typical learner misconceptions when teaching about the construction?

Participant 4: Yeah, the misconception is that especially when coming to the effect of current, what current can do, is they think we are just talking. There is something that should be driving the motor except for the power so that is what they mostly argue with me about until it is until it is proven until we connect the motor to to a supply.

Researcher: D1. Next question here. What teaching strategies will you use to teach this construction?

Participant 4: The teaching strategies that I use is it is a practical one, a visual one whereby the parts will be shown as visually on the screen and then thereafter a motor is taken, and it is dismantled and the parts are also shown to the learners. Let them have a feeling of those parts, touch them and that is what I want to do.

Researcher: D2. The next question, what questions will you consider important to ask in your teaching strategy? Questions you normally ask when you teach construction?

Participant 4: I would normally ask learners the major parts of a motor and then which they will answer me which is the stator, the rotor and the frame and those parts they never forget them. So that is the starting point when I want them to scratch the concept with regard to the parts, the main three parts in the motor.

Researcher: E1. Thank you. What presentation will you use in the teaching strategies? The presentation will refer to teaching media.

Participant 4: I do use YouTube and I also use… I go to the websites where we can find any information about motors and induction motors together with the application just for about 10 minutes so that we see that these are real things that are used in the real world.

Researcher: Thank you. What way would you assess learners understanding?

Participant 4: Normally use, I start with long questions. Long questions I refer to things like name the parts of your motor. It's a big longer. Some will name three, some will name five and then I will also use multiple choice questions and I will have class tests, weekly class tests on a part on the topic, and I will tell them the questions that I will be asking so that they prepare for those questions and if they fail then it is because they did not read. then that is where you now know that they did not read. I don't hide the questions that I will be asking them in the class test or the weekly test. It is just to make sure that they are ready to prepare.

Researcher: And for the first big idea, it seems like we are done.

Big idea 2: the types of motors

Researcher: A1. so, we done the first big idea. We now going to look at the second big idea of which it's the types of motors. Okay. The first question again, what do we intend learners to know about the types of motors?

Participant 4: They should know that some motors use dual supply. There are motors that you can use DC and also AC and that is their base from grade 11. But in grade 12 with regard to three phase motors, they should only know that three phase motors cannot use DC supply. They only use AC supply.

Researcher: A2. Um, why is it important for students to know about the types of motors?

Participant 4: It's important because we are grooming them for the outside world where they will be using these motors. Yes. And the skills that are required, the skills that they should know from the school already, that you can never put an AC supply on a motor that is supposed to take DC and same with the AC motor to take DC. So, they should know the different, especially with regard to what is making this motor to be more effective and so on.

Researcher: A3. Um, next question, what concepts need to be taught before teaching them about the types of motors?

Participant 4: The concepts is, uh, magnetism, mutual induction, self-induction. Those are the three concepts that need to be taught, uh, before going deeper into it.

Researcher: A4. Um, what else do you know about the types of motors that you don't intend learners to know yet?

Participant 4: So far, there is none that I know.

Researcher: B1. Um, the next question, what do you consider difficult about teaching the types of motors?

Participant 4: There is nothing that I see to be difficult. It is only a simple concept of differentiating the types of motors, uh, because they do have different, uh, parts and it is not something that is difficult.

Researcher: C1. what are the typical misconceptions when teaching about the types of motors?

Participant 4: Uh, the misconception is that, because on the single-phase motors, they see on the, uh, inspection box, you will have three, I mean, six points in the three phase motors. We have six points. They think that this motor has been wired at the same, but why can't we just take out the capacitance and, uh, put the power straight onto, onto the motor so that the motor can run. So, they sometimes want to experiment that of which it will not work. So, it's a misconception. They just think that, uh, capacitance are just used for fun. And until they themselves disconnect capacitance and try to, to do it, of which I will not allow them to do, because it might be dangerous.

Researcher: D1. Um, what teaching start teaching would you use when teaching about the types of motors?

Participant 4: Uh, I start with a learner centred whereby they themselves, they go through the content of motors and then they come and explain about it, explain to the whole class. Each and every learner will get a topic, a small topic into which they, uh, dig and then come and explain. And thereafter, that is when I come in and then I think that's the best strategy because now they are doing this for the second time. They did it alone and then I come in, they do it for the second time. And then when I give them work to go and do it home, like preparing for a class test, it is again. So at least there will be some information that is dwelling in their brains.

Researcher: D2. the next question then, uh, what questions would you consider important to ask about the types of motors?

Participant 4: Uh, it's just naming the type of motors that are available and their applications.

Researcher: E1. Um, what representations would you use in your teaching strategy?

Participant 4: Uh, I use the media and I also use the textbook. Okay, textbook content there.

Researcher: if I'm not mistaken, this is the last question about the types of motors. Uh, what ways will you use to assess the lemmas understanding?

Participant 4: Yeah, my way is to remain the same. I believe in, uh, multiple choice, weekly tests. The home and class activities are not that effective because they do a copy from each other and so on. So, the method that I believe in the most is the weekly, weekly class tests.

Big idea 3: application of motors

Researcher: Okay. Right. Uh, no. Um, okay. Uh, so now I'm going to look at the third big idea. Okay. Can you give me the third big idea?

Participant 4: Its application of motors.

Researcher: A1. Okay. Uh, then let's answer the following questions about application of motors. Uh, what do you intend learners to know about application of motors?

Participant 4: They should know that, uh, motors that are used in, uh, homes, they can also be used in industries.

Researcher: A2. Thank you. Uh, why is it important for learners to know about the application of motors?

Participant 4: It is very important that that will, uh, sharpen their, their skills and knowledge, uh, because they do meet this or see these motors, but they will not know where they are and where they are used. So, when they see them at home, they should know that these are single-phase motors. And when they see them being used in industries, then they should know that industries normally use three-phase motors, but they can be a combination also in industries of single-phase and three-phase, but at home, because we do not have three-phase. So, they should know that the motor that they saw at home being used is a single-phase motor.

Researcher: A3. Thank you. Um, what concepts need to be taught when teaching about application of motors? Or before, sorry, what concept needs to be taught before teaching about application?

Participant 4: it is the safety. So, it is safety with regard to the usage of motors.

Researcher: Okay. Anything else?

Participant 4: Uh, I think that's the bigger one. That's the most important one.

Researcher: A4. Yes. Thank you. Um, what else do you know about, uh, the application of motors that you don't intend learners to know yet?

Participant 4: Uh, it is to understand that, uh, three-phase motors sometimes can be used in conjunction with other devices, uh, to be used on a single-phase device.

Researcher: B1. Uh, the next question is, uh, what do you consider difficult about teaching the application of motors?

Participant 4: What is difficult is getting to the real places where these motors are being used in the real world, because of the time that we are having with these children here, because of the workload that we have to administer. So the time for excursions to different places is a bit limited, and sometimes not available.

Researcher: C1. Um, what are typical learner misconceptions when teaching about applications?

Participant 4: So far, I did not have any challenges in terms of the application. Okay. We just take them as they are.

Researcher: D1. All right. Thank you. Uh, what teaching strategies will you use when teaching about application of motors?

Participant 4: It is just a normal question and answer through in the class. And I normally say there was not only three applications of each motor, so that they do not forget them, uh, for the purpose of the exams. And they are more than three, but they should only choose the three of the best that they know, because there's no question paper that can ask more than three applications.

Researcher: D2. Uh, and let's see, uh, what questions would you consider important to ask when teaching about applications?

Participant 4: Can you repeat the question?

Researcher: Uh, what questions do you normally ask when teaching applications? Normally ask learners.

Participant 4: I just ask questions like, uh, which motor can be used to drive an elevator? Which motor is used, uh, for lathe machines? Those are the type that I ask so they should know or write one application of induction motor. So, these are the types of question I ask. So, they should know where it is used. And they should also know that this particular device uses this type of motor.

Researcher: E1. Thank you. what representations will you use in your teaching strategy?

Participant 4: I use the media, YouTube. And I also use the ones that are in class, the physical ones that are in class.

Researcher: Okay. The physical motors?

Participant 4: Yes. Okay.

Researcher: our last question, what ways would you what ways would you use to assess the learners understanding?

Participant 4: I still use the same method. Same method class tests. Multiple choice.

Researcher: Okay. And I think we, yeah, we, we have concluded, uh, is there anything else maybe you'd like to add, uh, in the interview here? Anything at all?

Participant 4: Yeah. What I would like to add is that, uh, the, we do offer practical activities and the practical time that we have in terms of, uh, the annual teaching plan (ATP) is not enough. We should have more time for the practical activities than as is. And as we look at the weighting of the theory and ATP, I think it should be equal. I mean, and the practical, yeah, it should be equal 50, 50. Uh, that will

lead to us, uh, producing more learners with more skills. But the way it is, is that we normally concentrate more on the theory part than on the practical part. And that also leads to the incompetence of educators because Practicals are less and then the theory is more. So, most teachers will enjoy the theory more than they're practical because of the system, the way it is. So, what should be done is to at least make them 50, 50. The weighting should be 50, 50. And the experience is that, learners enjoy practical more than the theory. Learners enjoy practical more than the theory. So, they will push the teacher to go into practical, neglecting the theory part of which is not possible because the teacher will already have a knowledge that the ATP must be completed. Every week has got its own part that must be completed. And if that is not done, then it is a crime in the department of education. So, the balance must be there. Because in the real world, truly speaking, the practical dominates. What we teach in theory is important, but it has less implications in practical because you can have somebody who did not do metric, who did not go through all this theory but very good in the electrical work. And also, just to add even if it might be out of the context is that universities, normally these days, I don't think they are doing practical with the teachers they are producing. Because we have new teachers now and almost all of some runaway just because of the practical work. And they just work, and they prefer to take another subject, mathematics.

Appendix E5: Interview 5

Big idea 1: The construction of a three-phase motor

Researcher: A1. the first question here, um, what do you intend learners to know about the construction of a three-phase motor?

Participant 5: they have to know all the purposes of the parts of the motor and how those parts of the motor work and how they operate.

Researcher: A2. the next question, why is it important for students to know about the purpose of the motor and the parts of the motor, the things you mentioned?

Participant 5: uh it's important because some of the students maybe want to become electrical engineers, so they have to know how those parts operate, how to fix, and the effects of the parts on the motor. Like the squirrel cage of the motor, what is its effect on the motor. What happens with the rotor part, and the stator part.

Researcher: A3. uh the next question is what concepts need to be taught before teaching learners about the construction of the motor?

Participant 5: the concepts that must be taught to the learners are about the understanding of the motor. The whole parts in the motor how do they function, how does it work before we go deep to the parts of the motor. They must understand the construction and the application.

Researcher: A4. um next question is uh what else do you know about the construction of a motor that you don't intend learners to know yet? something maybe you want to teach them in future after construction.

Participant 5: come again?

Researcher: what else do you know about the construction of a motor maybe that you don't intend learners to know yet? Like when you teach them construction is there something that you feel like "I'm not supposed to teach them now" maybe you will teach them at the later stage?

Participant 5: yes, the assembly of the motor, the connection of the motor inside of the motor inside of the motor.

Researcher: B1. um moving on to the next question what do you consider difficult about teaching the construction of the motor?

Participant 5: uh it's part of this is it's like uh the learners they are struggling how to operate just taking operation of each component or both of each part of the motor or they are struggling to understand the uh the operation they know the same operation of the uh part of the motor but some of them they didn't know how to operate before they understand the operation of the parts. uh what the learners find difficult about the construction is to state the operation of each part of the motor.

Researcher: C1. okay um the next question what are learners typical misunderstanding when teaching the construction?

Participant 5: the squirrel cage rotor, how does it link to the bearings, how do they work together until the rotor rotates. How does the rotor link to the other parts?

Researcher: D1. um the next question, what teaching strategies would you use to teach the construction of the motor?

Participant 5: I will break down the questions in order for the kids to understand. Kids must understand the terms, and those terms are broken down so that it can be easy to understand.

Researcher: D2. uh next question, what questions would you consider important to ask uh when you are teaching the construction?

Participant 5: to label the parts, write down the purpose of the parts.

Researcher: E1. um next question um what representations do you use in your teaching strategy? When you teach about the construction, what teaching media do you normally use?

Participant 5: I'm using powerpoint to project the parts of the motor separately, use charts as well as the videos.

Researcher: then the last question about the construction is uh what ways would you use to assess learners understanding?

Participant 5: please come again?

Researcher: how do you assess learners understanding of their parts of a three-phase motor

Participant 5: I give them short, controlled tests based on the parts that were done in class, and short controlled classwork. Then I mark them so we can do corrections.

Big idea 2: the principle of operation

Researcher: A1. now uh the first question under the principle of operation is uh what do you intend learners to know about the principle of operation?

Participant 5: they have to know how does the motor operate. It is important to know how the motor operates and different types of motors, those with brushes and those without. So, they have to know how they operate individually.

Researcher: A2. the next question is why is it important for students to know about the operation of the different types of motors?

Participant 5: they have to know that we have different types of motors and each of them operate differently.

Researcher: A3. and next question uh what concepts need to be taught before teaching them about the principle of operation?

Participant 5: the important things are the parts of the motors, because you have to teach learners that in order for the shafts to rotate, what is happening before and what's happening from the supply to the squirrel cage to the rotating part, the stator, and the rotor.

Researcher: um yeah i can't hear you there at the end there.

Participant 5: yeah, I am not sure if I am explain it correctly.

Researcher: okay uh let me let me rephrase the question then. Under the principle of operation there are a lot of things that learners need to know right? So, the question is what are the things that they need to know maybe from previous grades that are going to affect the principle of operation?

Participant 5: like they have to know the main parts of the motor and how those parts in a motor link up, what do they do. Like the stator, the rotor, and the effects of the main parts

Researcher: A4. um the next question um what else do you know about the principle of operation that you don't want learners to know yet?

Participant 5: how to reduce the magnetic hum on the motor, to increase the rotational speed and how to avoid cogging on a motor.

Researcher: B1. moving on to the next question um what do you consider difficult about teaching the principle of operation?

Participant 5: sometimes the learners have a misunderstanding of the principles of the control circuits.

Researcher: C1. um next question what are typical learners and misconceptions when you teach about the principle of operation?

Participant 5: most of the time it is the terms we are using on principle of operation. Those terms are not well understood by the learners.

Researcher: D1. uh next question uh what teaching strategies will you use when you are teaching about the principle of operation?

Participant 5: something I do is to write them in point form so that it is easy for learners to understand, than writing in paragraph form. I put them in point form, like from the supply to the motor, then explain the function of each part in the motor because all the parts have their role in the operation.

Researcher: D2. let's see our next question uh what questions will you consider important to ask when you are teaching the principle of operation?

Participant 5: before I go to the principle of operation, I just ask the learners about the functions of those main parts of a motor. Then we can start with the operation once learners remember the functions of the parts. Lastly, we combine everything. Researcher: E1. next question uh what uh representations do you use in a teaching strategy? The teaching media what do you use when you teach principle of operation? Participant 5: I use videos from YouTube, they are easy to use and for learners to understand. When we talk about the rotor, the rotating part, I would show them from the video on how the rotor gets to rotate. Researcher: uh then the last question about the principle of operation uh what ways will you assess learners understanding? Participant 5: I just give them the controlled classworks, and I give them time to complete the activity. When the time has elapsed, I collect the papers and we do corrections. Researcher: do you sometimes use previous exam question papers as well? Participant 5: yes, we use previous exam question papers from different provinces.
Big idea 3: the testing of a three-phase motor Researcher: A1. okay uh so now we're looking at the the the third big idea of which is the testing of a three-phase motor. The first question about testing a three-phase motor, what do you intend learners to know about the testing of a three-phase motor? Participant 5: before you use the motor, you need to test if the motor is in a proper state to be used. You cannot use the motor without any testing. You need to test to make sure that the motor is in a good condition to be used. Researcher: A2. why is it important for students to know if the motor is in a good state to be used? Participant 5: for their own protection and to protect some of the components on the motor so that it cannot be damaged. Researcher: A3. uh what concepts uh need to be taught before teaching about uh testing of a three-phase Motor? Participant 5: they need to know the importance of testing and also, they need to know how to test a motor, and they need to know also the dangers that may arise if a motor is not tested. Researcher: um so okay just to clarify the question, when we speak of the importance of testing, the danger of a motor, it means already they already know the testing tools that you use isn't it? Participant 5: yes. I always tell them which tool to use when you test the motor and how to use that tool.

Researcher: A4. next question, what else do you know about the testing of a motor that you don't intend learners to know yet?

Participant 5: the mechanical inspection, like when they need to check inside of the motor as to which components are damaged. The testing of the inside of the motor does not need to be done.

Researcher: B1. uh moving on to the next question, what do you consider difficult about teaching about testing of a motor?

Participant 5: testing insulation resistance between windings. Some of the learners do not understand why we have to do the test, since the wires are already insulated. The learners also do not know what is the maximum value to get when testing for insulation resistance on the motors. They are also struggling with the correct setting for the megger tester, the correct range to select.

Researcher: C1. what are typical learner misconceptions when teaching about testing?

Participant 5: it is the use of equipment, because the learners are not sure which tool to use for performing which test. Sometimes the learners use the multimeter to perform the continuity test and the insulation resistance test.

Researcher: D1. uh next question yeah what teaching strategy will you use when you are teaching about testing?

Participant 5: I use the demonstration and a video on how they test that motor, then I switch off the video and give them a chance to test the motor without looking at the video.

Researcher: D2. next question about this uh what questions would you consider important to ask when you are teaching about the testing of a motor?

Participant 5: which inspections are done on a motor? Under the inspections learners have to explain how each inspection is performed.

Researcher: E1. um next question what representations do you use in your teaching strategy? What teaching media do you normally use in your teaching strategy?

Participant 5: I use PowerPoint, videos and also charts.

Researcher: and the last question, what ways would you use to assess learners' understanding?

Participant 5: I use different types of question papers from different provinces, and also using questions from different textbooks.

Appendix E6: Interview 6

Big idea 1: the construction of a three-phase motor

Researcher: A1. What do you intend learners to know about the construction of the three-phase induction motors?

Participant 6: Okay. I want my learners to be able to know about the parts of the motor, the inner and the outer parts of the motor.

Researcher: Is there anything else? Maybe just mention them as they come to your head.

Participant 6: I just want them to know a function of each part of the motor. And what else do I want them to know? I want them to know how each part is connected to the motor.

Researcher: Is there anything else?

Participant 6: Yeah. I think that is all.

Researcher: A2. Now the next question. Why is it important for students to know about the parts of the motor, the function of the parts, and how each part is connected to a motor?

Participant 6: I think it's important for them to know about the parts of the motor because they can be able to understand each and every part of the motor what it does to the motor whenever it's operating. And as well they can be able to test if there's any fault, they can be able to detect which part has a fault. And also, they can be able to name the parts instead of not knowing which part is which one. Also, they must be able to identify the parts of a motor.

Researcher: A3. Our next question is what concepts need to be taught before teaching them about the construction? What do they need to know from previous grades maybe?

Participant 6: From previous grades they need to know about single phase motors which they've done in grade 11. They are familiar with single phase motors but now they'll be doing three instead of single phase. And then what else do they need to know? I think they need to know assembly. Assembly of parts. Because after we teach them about the parts of the motor, we want to take them out and they need to know how to assemble how they were. And then what else do they need to know? They need to know about the connection I think of the parts of connection of parts. I think that's what they need to know.

Researcher: A4. Next question. What else do you know about the construction? Is there anything extra that you know about the construction that we haven't mentioned? That you don't attend learners to know yet. You don't want them to know it now. Maybe you will teach them at the later stage or something.

Participant 6: I think what my learners don't know about the construction of the motor is that some of the parts are not electrically connected but they work through magnetism. So, I think they're not familiar with that concept. They don't know that some of the parts are not electrically connected but they work with the principle of magnetism.

Researcher: B1. Still under construction. What do you consider difficult about teaching construction? That learners are struggling with as we are teaching.

Participant 6: That learners are struggling with?

Researcher: or even you maybe you are struggling with teaching that specific thing. Just look at it from both sides.

Participant 6: I think what I'm struggling with is understanding the connection of the terminal box of the windings before the testing part. I think it's the connection of the terminal box of the windings before the testing part. Yeah. What else? That I think my learners have a challenge on.

Researcher: If there's nothing else it is okay.

Researcher: C1. Next question. What are typical learners misconceptions when teaching construction? Something they think is supposed to be this way but it's not.

Participant 6: They think that all the parts of the electrical motor work with the electricity. So, before you teach them about the operation that is what they think until you let them know that the operation is totally different to how they thought things were.

Researcher: So, all the parts are electrically connected. That's what they think.

Researcher: D1. Let's move on to the next question. What key teaching strategies will you use in the construction?

Participant 6: Okay. I will use a physical motor.

Researcher: Is there anything else maybe?

Participant 6: That we no longer use. An old motor. Dissemble all the parts. Show them one by one. Each part and explain each function of the part. Dissemble all the old motor that we are no longer using.

Researcher: D2. The next question here is, what would you consider important to ask in a teaching strategy? Like the questions that you will be asking the learners as we are teaching about the construction.

Participant 6: The questions that are about asking them?

Researcher: The questions that you normally ask when you teach construction.

Participant 6: Identify the parts of a three-phase motor. Which are similar to the single-phase motor because I believe that they've already done the chapter. So, some of the things they might be familiar. It would be something new. Researcher: Is there any other questions you might ask maybe? Participant 6: Any other questions that I might ask? I might ask them to identify I can even ask them if they know any parts of the motor. I think some of them, they are familiar with them from the devices that they use at home. It's not something that is new. For instance, something that they can see physically. Yeah. Which is something that they can say, this is a fan, this is a nameplate and all those things. Researcher: E. I think that will be the second last question. That will be what representation will you use in your teaching strategy? Representation teaching media. Participant 6: Teaching media. Now I will have a physical motor as well as projector. I will use an overhead projector. They also have a motor panel which consists of different types of motors, both single and three-phase which they can use. Researcher: The last question is what will you use to assess learners understanding? Participant 6: What will I use? Researcher: To assess them. They understand this thing you just taught. Participant 6: I will use their activity book as well as I can give them a task to assemble the parts of the motor after we disassemble them. They can assemble them back so that I can test if they do understand where each parts is supposed to be. So, they can take the parts back to where they how they may before we assemble the motor.
Big idea 2: the principle of operation Researcher: A1. First question about the operation. What do you intend learners to know about the operation? Participant 6: How the motor works. The efficiency of the motor. How it starts. It's starting torque. How it starts. And the synchronous speed as well as the rotor speed. Researcher: A2. The next question. Why is it important for learners to know how the motor works? Participant 6: So that they can be able to fix the motor. I will say that they can be able to operate the motor. So that they can be able to understand the motor itself. Okay. Because they are going to use it even afterwards, after completing grade 12. When they do electrical engineering, they're still going to work with bigger, even bigger, or smaller motors. So, this is what they are going to face on daily basis.

So, they have to know how it works. So that they can identify as well as the faults on the motor. Fault finding.

Researcher: A3. Next question then. What concepts need to be taught before teaching them the operation of the motor?

Participant 6: I think you need to teach them about the principle of magnetism. The principle of magnetism. And then all the laws that are needed Faraday's law. And what else that you need to teach them? you need to teach them about the construction. I think the construction of all the parts so that they can know how does each part contribute to the function of the motor.

Researcher: A4. let us move on then to the next question. What else do you know about the operation that you don't intend learners to know yet? When you teach them on how the motor works the efficiency and how it starts and synchronous speed. Is there something that you don't want them to know yet? Maybe you will teach them at the later stage.

Participant 6: What I will teach them at the later stage is how to change the rotation of the motor. I think it must come at the end after they understand how it works.

Researcher: B1. Move on to the next question then. What do you consider difficult about teaching construction?

Participant 6: what do I consider difficult the operation?

Researcher: Let me rephrase the question. What do you consider difficult about teaching the learners the operation?

Participant 6: I think the learners need to understand the laws first before they can understand the basic operation. So, they don't understand the laws of for instance, like for instance Faraday's laws all those laws that we need to know before we can actually know the operation of the motor. So, I think they don't understand them first. All those rules that they need to understand before we tackle the topic.

Researcher: C1. What are typical learners misunderstanding or misconceptions rather when teaching the operation?

Participant 6: Misconceptions. Okay. My learners, they think that because now when you open the inner part of the motor, we are not able to see the magnets or the magnetic poles within the stator. They find it difficult to understand how is it possible that it works with the principle of magnetism while they don't see the physical magnets on the stator of the of the motor. So, I guess you just need to explain to them that they are there even though they are not able to see them but they are there. That is how it makes the rotor to turn. So yeah. I don't know if I put it well.

Researcher: D1. What teaching strategies will you use to teach the operation?

Participant 6: Okay. Because now the operation you can't teach your learners without them seeing the physical video. I think it's important for any teacher to use an overhead projector whereby the learners will be able to see the inner part of the motor in a form of a video, rather than explaining to them the theoretical part which they are not able to see with their naked eyes. So, a video is better than telling them something that they will not be able to see. Because even if you can tell it on, they will not be able to see what is happening inside the motor, but once you use a video, a video will be able to show them what is happening to the rotor, the state, the parts within them won't. So, I think a video will be user-friendly for you to explain to the learners. Rather than reading them a theory part in which they are not even able to see.

Researcher: D2. What questions will you consider important to ask in your teaching of the operation?

Participant 6: what is that law?

Researcher: So, the question is what questions would you consider important to ask in a teaching strategy?

Participant 6: Okay. I'll ask them about the Fleming's left-hand rule. Is it left, or right? I think it's right hand. Right hand rule. That will help me to address the importance of them knowing the direction of the magnetic field lines because now the concept or the operation of the motor is based on magnetism. So, they need to know each and everything to do with magnetism. And I will also ask them about the principle of magnetism from grade 10 which is something that they are familiar with. So, it's not something that they start in grade 12. And then what else will I ask them? The questions that I will ask my learners is where do they think we see motors? Where do we use them? Where have they seen them?

Researcher: E1. Yes. What representation will you use in your teaching strategy?

Participant 6: Teaching media is a projector, YouTube videos for them to watch. Select the ones that I think that will be able to link with the prior knowledge that they have. Yeah. I'll break them down easily, step by step so that I can see that this one must be first, second one, and so forth.

Researcher: Thank you very much. The last question will be, what ways would you assess learners understanding? How would you assess their understanding of the operation?

Participant 6: Okay. I'll use a previous question paper. Ask them to write the principle of operation of a motor.

Researcher: Is there anything else?

Participant 6: Ask them to write the principle of operation of the motor. Also, they can also use their practical assessment task simulation. They can answer questions from there after completing the activity of the operation. I'll select some activities from the practical assessment task, which are based on the operation of the motor.

Big idea 3: Testing of a three-phase motor

Researcher: A1. The first question about testing is, what do you intend learners to know about testing a motor?

Participant 6: I want my learners to know how to test the insulation resistance between the windings. And then, how to test the connection of the motors, the connection of the windings, sorry.

Researcher: What else do we have? Is there anything else?

Participant 6: There are three tests basically. The insulation resistance to the windings and the other one has to do with the earthing of the motor. The continuity resistance test.

Researcher: A2. Why is it important for learners to know about the tests you mentioned above?

Participant 6: so, they can be able to identify any fault. Between the motor and the windings. And they're able to test the motor before they can even operate it. Yeah. Before you even switch it on, they're able to test it first if everything is okay.

Researcher: A3. So, let's move on to the next question. What concepts need to be taught before teaching the testing of the motor?

Participant 6: I think you need to teach your learners how to use the testing equipment that they'll be using to test the motor. Which is the megger tester. They must be familiar with it. know how to use it before they can even test the motor. And then you need to teach them about the connection of the windings within the motor. When they open the connection box, they need to see which one goes with the other one and which one goes with the other one. The pairs of the windings.

Researcher: A4. Next question. What else do you know about the testing of a motor that you don't intend learners to know yet?

Participant 6: Are the readings, I don't want them to know about the reading first. They must find out what are the requirements that are needed for their motor to fully operate which readings must they get currently for their motor to operate? They need to know the exact readings that which are acceptable for their motor and which readings are not acceptable for their motor to operate. So, I think it's okay if they figure it out themselves rather than me telling them before.

Researcher: B1. Next question then. What do you consider difficult about teaching testing a motor?

Participant 6: What do I consider difficult? I think the safety usage of the testing tool and again I think what is difficult is the amount of voltage which we put there. It's difficult because we work with the learners who can do some of the things with the testing equipment. So, I think we need to be careful as teachers when we use that testing equipment. So, the voltage when we test the motor is too high. Those are some of the challenges that will face because now we are dealing with three-phase. We need to put twice the voltage that the motor has.

Researcher: C1. Next question. What are typical learners' misconceptions when teaching about testing?

Participant 6: I think because they look at the nameplate of the motor when before you can even tell them that they need to put the voltage to 1000. They think that because it's 400 volts they need to use 500 volts on their test. Or if it's 400 it's there then they put 400 because they don't know that you have to put twice the voltage on their test that. So, they think that they have to put the exact reading that they see on the nameplate of the motor as the same they say it's the same reading when they tester.

Researcher: D1. What teaching strategies will you use when you teach testing a motor?

Participant 6: strategies that I will use. I will start demonstrating first how can they use the equipment or demonstrate first. Before I can give them the equipment because the amount of voltage that we use is 1000 which might be dangerous if learners play with the leads of the megger tester. So I was that demonstrating showing them first before they can actually do it so that they can know what is it that is expected from them. And what else can I use? I think I can also use a video. I can use a video by they see a person and testing a motor and what else I can use. I think because they are familiar with testing a single-phase motor it won't be a challenge that much because already they have that simulation whereby they tested a single phase motor in grade 11 but now it's no longer single it's three-phase. So yeah. It's not something that is new.

Researcher: D2. And the next question is what questions would you consider important to ask when you are teaching?

Participant 6: Questions that I think are very important. I will ask them what readings do they get between the windings which are connected which what readings are they getting or their megger tester.

Researcher: Between the windings?

Participant 6: Between the windings. And then what else will I ask them? I will ask them before they can even test the type of connection in which the motor is connected. Is it star or delta? Do they know if it's star or delta or show them first all those things. The type of connections that the windings have. And then I will ask them after inspecting the motor from the readings one to which they got is it safe for us to operate the motor? Is the motor acceptable to operate or it's not acceptable? And they must give me the reasons why they think the motor is not acceptable. To be operated by people or industries or whoever will use the equipment.

Researcher: E1. The next question is what representation will you use in your teaching strategy?

Participant 6: I will use a motor. A physical motor, it must be there. And then it must be disconnected from the supply because we work with safety first. And then I will also use a megger tester as well as a video.

Researcher: So, on the previous question just to recap. You said you use a physical motor that is disconnected for safety reasons? You said you lose a megger and a video?

Participant 6: from YouTube. And also, I can demonstrate first. So that they can know what is expected from them.

Researcher: So, our next question then, what ways would you use to assess learners understanding?

Participant 6: I will use the practical assessment task which my learners have where they are required to test the motor. And as well, I can give them a physical motor and they test it while I'm looking at what they are doing.

Researcher: concluded our interview.

Appendix F: Subject Advisor's Biographical Information

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