

**Exploring Grade 9 Natural Sciences
teachers' pedagogical content
knowledge of electricity in Moses
Kotane Area Office, North West Province**
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DECLARATION

I, **Joyce Godisamang Poti** declare that this study: **Exploring grade 9 Natural Science teachers' PCK in the teaching of Electricity in Moses Kotane Area Office, North West Province** is my own work apart from where sources are acknowledged.

This study is for the degree Master of Education, submitted to the Faculty of Education, North-West University, and has not been previously submitted by me or any other person for a degree at any alternative institute.



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DATE: 22 November 2019

DEDICATION

This work is dedicated to my mother, Lizzie Mphoreng Poti and my daughter Keabaka Poti for believing in me and being my source of strength.

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Firstly, I thank God, the almighty for keeping me and giving me strength to finish despite being sick through the journey.

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ABSTRACT

The purpose of this study was to explore Grade 9 Natural Science teachers' PCK of the topic - Electricity. It looked at teachers' orientations to science teaching, their Subject Matter Knowledge (SMK) and Topic Specific Pedagogical Content Knowledge (TSPCK) and implementation of Grade 9 Natural Sciences (NS) CAPS curriculum. The study employed an interpretive, qualitative, multiple case study to generate data. Data were collected by means of workshops, classroom observations and semi-structured interviews. An intervention was conducted with the hope of strengthening the teachers' PCK of the topic - Electricity. Qualitative data were inductively analysed using the IMTPG model and components of PCK.

Two professional development workshops were conducted and the objectives were: to ensure that teachers are able to explain and demonstrate an understanding of basic Electricity concepts; to be able to use appropriate and relevant methods to teach basic electricity concepts; to acquire knowledge on conducting practical experiments on electrical circuits and how to employ various teaching and assessment strategies on the topic - Electricity. The workshops focused on important content and attended to the context that supports and guides teacher learning.

The study revealed that teachers' pedagogical content knowledge, knowledge of science curriculum and topic-specific content improved during the intervention workshops. An interesting finding of this study is that teachers' knowledge of instructional strategies and approaches as well as tools to use in teaching was enhanced during the workshops as professional development interventions.

With regards to teachers' content knowledge and beliefs, the findings of this study revealed that teachers displayed meaningful patterns of information on their goals for science teaching. It was also found that teachers' pedagogical orientations are influenced by learners' practices and behaviour.

From the study, it emerged that collaboration is important in supporting teacher growth. The teachers reinforced, expanded, and challenged their notions about teaching science and their PCK. The teachers' interaction during the intervention showed that they enjoyed focusing on content knowledge and instruction, and there was an improvement in certain areas of their pedagogical content knowledge.

Based on the aforementioned findings , this study recommends that teachers be taken through interventions for professional development programmes at the beginning of each term to enhance their pedagogical content knowledge. These interventions should be well planned and allocated enough time to run. The study also recommends that teachers should be provided with resources to teach science, especially laboratory equipment since the subject is a practical nature. It is easier for teachers to address learners' misconceptions by performing experiments which contradicts their prior knowledge. The study further recommends that teachers' orientations to science teaching and content knowledge be taken into consideration when developing the curriculum as well as professional development programmes. This was found to be a challenge since teachers rush to cover the Annual Teaching Plan (ATP) hence classrooms activities are teacher- orientated. For future research, this study proposes that an investigation into factors contributing to poor learner performance besides teachers PCK be explored. More studies should be conducted in order to curb this challenge and ensure that South Africa has adequately prepared and knowledgeable future scientists. It will be also interesting to find out what the results could be if the study was conducted with a larger sample across all the districts.

KEYWORDS

Pedagogical Content Knowledge

Content Knowledge

Science

Curriculum

Subject Matter Knowledge

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CHAPTER 1: INTRODUCTION

1.1 Introduction to the study

There has been a lot of curriculum changes in South Africa since 1994 but they have not yet yielded the desired results (Maimela, 2015). The country continues to perform poorly in international benchmarking assessments like Trends in International Mathematics and Science Study (TIMSS) and Progress in International Reading Literacy Study (PIRLS) (March, Foy & Arora, 2012; Reddy, Visser, Winnaar, Arends, Juan, Prinsloo & Isdale, 2016). The 2015 TIMSS report indicates that learners are still performing below the international benchmark at Grade 9 in science subjects. This calls for a need to look at what is exactly happening in our classrooms, the unique knowledge and pedagogy that individual teachers possess to teach mathematics and sciences so as to fully understand the dilemma. According to Toerien (2013), a successful education system is critically dependant on the quality of the teaching involved. The Centre for Development and Enterprise (CDE) reports that the quality of teachers are very important for an efficient education system (CDE, 2007). In order to describe the knowledge that teachers create by transforming the content they know into a teachable form, Shulman (1986) published the first paper that introduced the phrase pedagogical content knowledge (PCK). Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) argue that PCK also provides an integral role for subject matter knowledge in pedagogy for effective teaching. However, in teaching contexts where teachers' subject matter cannot be taken for granted, PCK is even more important.

Science is a social construct that places importance on certain norms and interactions needed to construct knowledge (NRC, 2012). Teachers require specialized PCK of topics such as Electricity to be able to teach it in their classrooms. Studies conducted on the relationship between classroom practices and teachers' content knowledge practices indicate that PCK is influenced by the teacher's content knowledge hence the ability to implement different strategies in their classrooms (Ramnarain, 2013). Electricity is a topic which is taught from Intermediate Phase right through to Grade 12. It is the basis of most scientific concepts, but most importantly it impacts on the learners' everyday lives. It is found that there are a lot of misconceptions that arise from both learners and teachers' initial knowledge of electricity hence the poor performance (Ramnarain, 2013; van de Merwe, 2014).

Teaching learners basic electric circuit functions is one of the difficult pedagogical challenges according to some researchers (Hart, 2008; Jaakkola, et al. 2011). Moodley (2013) asserts that

there are concepts central in electricity which are abstract by nature. He further states that learners may find difficulty in mathematical manipulation at Grade 9 level for some calculations. Gunstone (2008) reports that in most electricity classrooms more emphasis is on calculations rather than on practical work and conceptual understanding. Recently, Mackay and Hobden (2012) reported that it is important to understand learners' misconceptions on basic electricity circuit. This study therefore finds credence in investigating the Grade 9 Natural Sciences teachers' pedagogical content knowledge of electricity.

1.2 Background to the study

Since 1994, South Africa has undergone a period of unprecedented curriculum changes which ultimately resulted in Curriculum and Assessment Policy Statement (CAPS) (Maimela, 2015). In the classroom, teachers expected to implement the intended curriculum hence they remain important role players (Leu, 2004; O'Sullivan, 2004; Schwille & Dembélé, 2007). Cole, et al. (2006) argue that the system is experiencing a range of challenges including lack of resources and teachers being either unqualified, or under-qualified. In the CAPS Curriculum, the Natural Science learning deals with the promotion of scientific literacy. This can be attained by using “ science process skills, critical thinking skills and problem-solving skills in a variety of settings, developing and applying scientific knowledge and understanding and appreciating the relationships and responsibilities between science, society and the environment” (DoE 2003: 4).

The Department of Basic Education Diagnostic report for 2015 and 2016 indicates poor performance on the topic of Electricity at grade 9 level. Nkopane, Kriek, Basson, and Lemmer (2011) concluded that learners have misconceptions in electricity and one contributing factor is teachers' lack of understanding of misconceptions. Teachers need to understand learners pre-existing knowledge to can effectively teach them (Morrison & Lederman, 2003). According to Ashwini (2010), to make learning more meaningful, teachers should possess extensive subject matter knowledge and understanding of how learners learn. Ball and Bass (2000) argue that the more teachers practice in class, the more they gain subject matter knowledge to facilitate learning.

Pedagogical knowledge is a construct that encompasses all issues of students' learning, from preparation to assessment (Hlaing & Maw, 2016). Various teaching strategies, methodologies and assessment tools are included. According to Mavhunga and Rollnick (2013), PCK as a theoretical construct is an attribute used in many teaching fields. Researchers in science education agree that

in programmes for teacher education, PCK is very important (Abell, 2007; Kind, 2009). Therefore, PCK has been defined as ‘the only knowledge used in classroom instruction that helps students understand specific concepts’ (Gess-Newsome, 1999, p. 12). PCK is unique to a teacher, it indicates that there are more activities to be engaged in than classroom teaching. Loughran, Berry & Mulhall (2012) assert that PCK as a construct evolves based on experience, teaching strategies and dealing with students’ understanding. This has a bearing on the teachers PCK since they implore different pedagogical strategies to deliver and share their knowledge in a manner that is understandable to learners, hence the intention to investigate grade 9 teachers’ PCK of electricity in this study.

1.3 Problem statement

Although learners and teachers agree that electricity is an important science topic, they view it as not easy to understand (Gaigher, 2014). It is therefore not surprising to find literature on misconceptions in electricity. According to Tambara (2015), studies to provide information on teacher’s pedagogical skills have been conducted. South Africa participated in 2015 TIMSS Study and the report indicates that it achieved an average score of 358 from a centrepont of 500 on the scale. Different categories of benchmarks are used to define achievement and these are: i) scores between 400 and 475 points are achievement at a low level; ii) scores between 475 and 550 points are achievement at an intermediate level; iii) scores between 550 and 625 points are achievement at a high level and iv) scores above 625 points are achievement at an advanced level. According to Reddy et al. (2016), the rank order of the provinces for TIMSS 2015 in order of highest to lowest percentage of learners who performed at or above the 400 TIMSS points mark for science was, Gauteng (48% of learners), Western Cape (44%), KwaZulu-Natal (31%), Free State (30%), Northern Cape (29%), Limpopo (27%), Mpumalanga (26%), Eastern Cape (23%) and North West (22%). According to the above results North West Province is ranked 9th out of 9 provinces, meaning it is the worst performing in the country. This clearly indicates a problem with Natural Science teaching in the province. For a question in Electricity, learners were given a diagram showing a battery connected from the negative pole to a resistor, then to an open switch, then to an ammeter, back to the positive pole of the battery. In that circuit the battery was 4.5 volts, the ammeter reading was 0.5 amperes, when the switch is closed. The question asked, what is the resistance? Almost the same proportion of South African learners (12.7%) managed to give a correct response to the item, comparing well with the international standard (14.7%) which is also very low. However, more South African learners got the item incorrect (almost 75%) compared to

the international standard (just over 60%). Learners need to understand circuits and resistance in order to apply it to the problem at hand. Learners did not know electricity theory and the application of the correct formula (Reddy et al. 2016).

The North West Department of Education (NWDoE) conduct annual assessments for all Grade 9 subjects. The performance of Natural Sciences in the North West Provincial Assessments (NWPAs) has been unsatisfactory from 2014 until 2016. In 2014, the performance was 32.9%, 28.7% in 2015, and 28.2% in 2016 (NWPAs, 2016). This is an indication that there might be a gap somewhere in teachers' knowledge of Natural Sciences. In 2016, learners performed poorly on all questions on electricity. According to Smith et al. (2013) it is not easy to teach and to learn because of its specificity and complexity. Given this background and also based on the many studies that confirmed the importance of teachers' PCK in teaching science, and the ones on learner performance in science, this study found it necessary to investigate the grade 9 teachers' PCK of electricity.

1.4 Research Questions

The main research question and respective sub-questions for this study are as follows:

1.4.1 Primary research question

The study aimed to contribute to a research-based practice of PCK development by addressing the following main research question:

- How does the teachers' PCK of Electricity concepts influence their teaching?

1.4.2 Sub-Questions

The following sub-questions guided this study:

- (i) How does the Grade 9 teachers' pedagogical content knowledge manifest during a proposed intervention?
- (ii) How does the teachers' orientation to science teaching influence their pedagogical content knowledge?
- (iii) In what ways do specific characteristics of the professional development programme contribute to shifts in the teachers' PCK?

1.5 Aims and objectives of the study

The aims and the objectives for the study are as follows:

1.5.1 Aim

The study's main aim is:

- To explore how teachers' PCK of electricity concepts influence their teaching.

1.5.2 Objectives

For the above aim to be achievable, the following objectives were set:

- (i) To investigate how Grade 9 teachers' PCK manifest during a proposed intervention;
- (ii) To determine how the teachers' orientation to science teaching influence their PCK; and
- (iii) To determine ways in which specific characteristics of the professional development programme contribute to shifts in the teachers' PCK.

1.6 Overview of research design and methodology

A qualitative research design was chosen for this study (Miles, Huberman, & Saldana, 2014). Qualitative approach was chosen because of its strengths as outlined by Castro, Kellison, Boyd and Kopak (2010:343): A case study design strategy was employed to answer the research questions and achieve the objectives. According to McMillan and Schumacher (2010), a case study is defined as a procedure that involves investigating all aspects of a system using a variety of data collection methods.

This study entails one phenomenon but involves different participants in a specific context hence a multiple cases study design was chosen (Woodlock, 2010). Each of the participants was treated as a separate case and compared during data analysis. The study sought to explore through a multiple cases' study, the Grade 9 Natural Science teachers' pedagogical content knowledge of electricity.

Purposive sampling was used in this study. Creswell and Plano-Clark (2011) states that purposive sampling involves identification and selection of individuals or groups of individuals having knowledge about a phenomenon of interest. The study was conducted in four secondary schools

in the Moses Kotane East Area Office of the Moses Kotane Local Municipality in the Bojanala District, North West Province in the Republic of South Africa. Four Grade 9 Natural Sciences teachers (one from each secondary school), all with more than two years' experience in teaching were sampled for this study. They have all been verified by South African Council of Educators (SACE) as being fit to teach in South African classrooms despite their nationality or country of origin. The teachers' PCK of electricity in Grade 9 was investigated through classroom observations, semi- structured interviews and professional development workshops.

1.7 Data collection

This study sought to obtain detailed information about teachers' PCK in teaching the topic- Electricity at Grade 9 level. Professional development workshops, lesson observations and semi-structured interviews were used as data collection instruments to explore Grade 9 Natural Sciences teachers' PCK of Electricity in this case study.

1.8 Analysis of data

Data obtained from professional development workshops, classroom observations and semi-structured interviews was all qualitative. The three data collection instruments used in this study produced only qualitative data, and no numerical data was collected. The data was transcribed, examined and selected for indications of teacher change using Clarke and Hollingsworth's (2002) Interconnected Model of Teacher Professional Growth (IMTPG) model. The IMTPG model uses four domains as the indicators of key elements of change (Clarke & Hollingsworth; 2002), namely: The External Domain (ED) contained the professional development; teachers' conceptions comprised part of the personal domain (PD) along with the teachers' knowledge and attitude. Furthermore, the domain of practice (DP) encompassed the teachers' practice and lastly, the domain of consequence (DC) involved the students' learning.

1.9 Researcher's role

In this qualitative study, according to Maree (2014:41), the researcher's role is a "collaborative partnership between the researcher and participants to collect data and analyze it, with the aim of understanding the research problem." As the researcher, in this study I played the role of an instrument designer, data collector, workshop facilitator, interviewer, passive lesson observer, data

analyst as well as reporter. I provided detailed information about the context of the research, ensuring that the research strategies for collecting and analyzing data were not compromised. I also ensured that I adhere to ethical guidelines, respected the participants and research sites and ensured that disruptions were minimized.

1.10 Delimitation of the study

The study focused on only four Grade 9 Natural Science Teachers in four secondary schools of Moses Kotane East Area Office even though there are 21 secondary schools. The four schools were purposively sampled. Its main focus was on their PCK of electricity as a topic which is taught up to grade 12. The teachers are observed and interviewed individually at their respective schools and not compared to each other. An intervention workshop to enhance the teachers' subject matter knowledge and PCK was also conducted.

1.11 Definition of concepts

The following concepts are defined in order that the reader may understand the context.

Curriculum

Adu and Ngibe (2014) explains curriculum as the offering of valued knowledge, skills and attitudes to students through a variety of activities at school which includes the learning standards or learning objectives they are expected to meet. In this study, curriculum is understood to mean all the necessary activities put in place by the education authorities to ensure learner development. It includes syllabus for different subjects, topics that teachers teach, assessment methods as well as resources to use.

Science

Science is the systematic study of the structure and behaviour of the physical world, involving experimentation and measurement and the development of theories to describe the results of these activities (Bowie, Cassim, De Beer & Whitlock, 2005:18). In this study, science is understood to

mean the pursuit and systematic application of knowledge and understanding the natural world using different methodologies and strategies in subjects such as Natural Science and Physical Science.

Teaching

Sequeira (2012:3) defines teaching as “a set of events, outside the learners which are designed to support internal process of learning”. For this study, it referred to the engagement with learners to enhance their knowledge and application of concepts and processes by the teacher.

Pedagogical Content Knowledge

Shulman introduced the PCK concept as ‘that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding’ (Shulman, 1986). In this study, it refers to the teachers’ subject matter knowledge, pedagogical content, knowledge of instructional strategies, and activities to teach this specific topic of Electricity.

1.12 Overview of chapters

Chapter 1: Introduction and background

This chapter offers an orientation of the study in detail. It entails the introduction, background to the research, key concepts, the statement of the problem, aim and objectives, research methodology, definition of key terms used in the study, division of the chapters and summary. Finally, the study overview is outlined.

Chapter 2: Literature review

Chapter two of this study, focuses on review of critical literature on teachers’ PCK, orientations to science teaching, professional development and implementation of Grade 9 NS CAPS curriculum. Factors affecting the teaching of Electricity at Grade 9 are also explored in this chapter.

Chapter Three: Research design, methodology

The chapter presents a detailed account of the research methodology. Research design deals with the research paradigm, approach and research type. The research methods outlined in this chapter include procedures, data collection strategies, tools and techniques to gather and analyse data.

Trustworthiness and ethical considerations regarding the participation of human beings in the study are also discussed.

Chapter Four: Data analysis, interpretation and discussion

This chapter deals with data analysis using IMTPG model as an analytical tool, interpretation as well as detailed discussion of findings of the data collected. It includes comparisons of findings of the study with reviewed literature.

Chapter Five: Summary of findings, conclusions and recommendations

This chapter provides the summary of findings of the study, conclusions on the basis of the analysed data as well as recommendations. Areas for future research, limitations of the study and final concluding remarks are also presented.

1.13 Summary

In this introductory chapter, a brief orientation to the study was provided, outlining the problem that was investigated and formulating the purpose of the study. *Exploring Grade 9 Natural Science Teachers' Pedagogical Content Knowledge of Electricity in Moses Kotane Area Office, North West Province*. The next chapter presents literature reviewed for this study from which arguments by various researchers were outlined. This chapter provided the orientation of the study. As part of the introduction, it discussed the educational and pedagogical foundations of the investigation. The problem statement and sub problems contained by this study were described along with the aims and objectives. Chapter one additionally discussed the research procedure which incorporated an explanation of the research design, paradigm, strategy and data gathering and analysis techniques to be utilized as well as ethical contemplations to be mulled over amid the research process.

The next chapter focuses on the literature reviewed for the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature pertinent to the study. The conceptual framework is provided which guides this study. Review of literature commences by exploring the concept of Pedagogical Content Knowledge as initially proposed by Lee Shulman in 1986. This is followed by the review of the importance of PCK construct and the construct of teachers' professional growth is also discussed. Different factors that affect the PCK of science teachers in teaching electricity are explored as well. The chapter ends by providing a summary of the study

2.2 What is PCK?

According to Wongsopawiro, Zwart and van Driel (2016), Shulman introduced the PCK concept as 'that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding' (Shulman, 1987). At the heart of PCK lies what teachers know about (a) how their students learn specific subject matter, (b) the difficulties or misconceptions students may have regarding this subject matter, and (c) their knowledge of instructional strategies, such as representations (e.g. models, metaphors) and activities (e.g. explications, experiments) to teach this specific subject matter. (Wongsopawiro et al., 2016). Wongsopawiro et al. (2016) further argue that these components are mutually related: 'The better teachers understand their students' learning difficulties with respect to a certain topic, and the more representations and activities they have at their disposal, the more effectively they can teach about this topic' (Van Driel, 2014, p. 849)). In this study focus was on all the three components of PCK as suggested by Wongsopawiro et al. (2016) to explore the teachers PCK of the topic - electricity.

Kind (2009) argues that in science education, PCK has been extensively researched but remains unpopular. However, there have been many studies with publicised results on misconceptions held by learners (Kind, 2009). Van Driel (2014) further argues that PCK unlike misconceptions remains unknown to most science teachers. There has been an attempt to describe the true nature PCK by suggesting changes to Shulman's knowledge types, developing taxonomies as well as different components of PCK. However, one might ask a philosophical question: what does 'true nature' mean? Also according to whose standards? It is not the purpose of this study to entangle this debate but focus is on teachers' PCK on the topic –Electricity.

2.2.1 Why is PCK important?

It is of utmost importance to understand the phenomenon of PCK since it is regarded as one of the cornerstones of teacher knowledge. Van Driel and Berry (2010) list these most important characteristics: PCK is constituted by a profound knowledge about subject matter (Krauss et al., 2008; van Driel, Verloop, & de Vos, 1998) connected with knowledge about how the students learn this respective subject matter and how to create a supportive learning environment. According to Kind (2009), PCK itself summarises a teacher's knowledge base, so does not exist as a separate type of knowledge. A transformative model defines PCK as the transformation of subject matter, pedagogical and contextual knowledge to create new knowledge for the purposes of instructing students.

Central to the notion of PCK is the idea that instruction can only be effective if it is attuned to the ways in which students learn specific content (Van Driel & Berry, 2010). Therefore, PCK has been defined as 'the only knowledge used in classroom instruction that helps students understand specific concepts' (Gess-Newsome, 1999). Both subject matter knowledge and teaching experience are vital to the development of PCK (Kind, 2009), hence pre-service or beginning teachers' PCK typically is very limited. However, the further development of teachers' PCK in the context of teaching practice appears to depend on various factors. Van Driel and Berry, (2010) has suggested that: "The development of PCK is perhaps best viewed as a complex interplay between knowledge of subject matter, teaching and learning, and context, and the way in which teachers combine and use this knowledge to express their expertise" (Van Driel & Berry, 2010, p.659).

Building from Van Driel & Berry (2010) this study will investigate PCK as a transformation of the knowledge pedagogy, content and context.

2.2.2 Models of PCK

Toerien (2013), in her study on investigating classroom practice of one science teacher in Cape Town, South Africa, indicated that a number of models to follow which have suggested that PCK is an *integration* of some or all of the other knowledge areas outlined by Shulman. Bishop and Denley (2007) conceptualised a 'spinning top' model in which there is merging of all the categories in Shulman's knowledge base. This model metaphorically depicts a spinning top that comprises of segments of different colours that are distinct and clearly separate from others when the top is

stationary, but the colours are blurred when the top is spun. The coloured segments depict Shulman’s proposed knowledge categories and therefore the new colour that results from the “spinning top” resembles the dynamic nature of PCK. It can therefore be argued that the PCK construct is not static and is created in the teaching environment through the skilful ability of the educator to merge the discrete knowledge bases (Bishop & Denley, 2007). In as far as science education is concerned, PCK distinguishes science teachers from scientists since it entails the translation of subject content for learners.

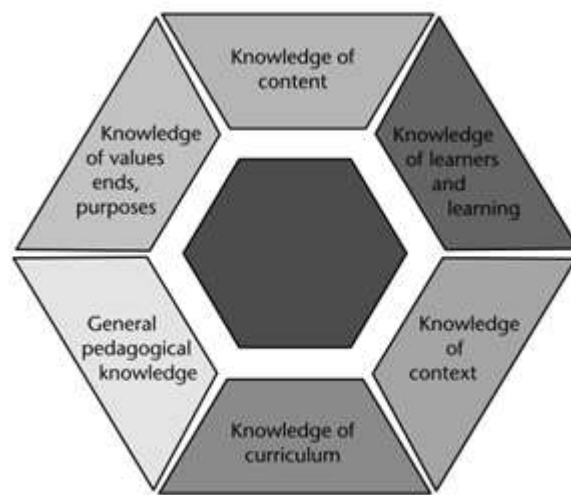


Figure 2.1: A “spinning top” model for PCK (*adapted from Toerien, 2013*)

Another model which conceptualised PCK according to Toerien (2013) is the ‘transformative model’ which highlights that sound knowledge of content knowledge and pedagogy as well as a transformation process are important for teaching to be effective. From this study, the implication for research is that all the aspects of PCK are to be jointly examined on a teacher.

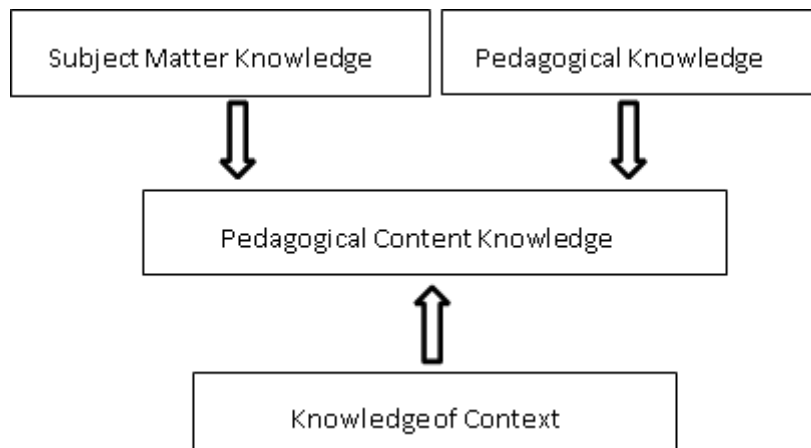


Figure 2.2: A transformative model of PCK (adapted from Toerien, 2013)

According to Toerien (2013), in the science education field, researchers like Magnusson et al. (1999) have developed further models of the key elements of PCK as manifested in actual teaching. Magnusson et al. (1999) in their model in addition to the knowledge categories have identified five distinct components of PCK which are:

- Orientation to teaching science
- Knowledge of the science curricula
- Knowledge of student's understanding of science
- Knowledge of assessment of scientific literacy
- Knowledge of instructional strategies

In this study, all the above models as presented by Toerien (2013) were implemented since they are an integration of all the PCK components that can be used to explore the grade 9 Natural Science teachers' PCK of electricity. The five PCK components by Magnusson et al. (1999) model were also used as a guide during data analysis in this study.

2.2.3 PCK within a Specific Topic

Aydin, Friedrichsen, Bozc, and Hanuscin (2014), assert that PCK is widely known to be specific to a topic. Mavhunga and Rollnick (2013) recently conceptualized a new term, 'topic-specific PCK (TSPCK)', following earlier authors (Loughran et al., 2004; Veal & MaKinster, 1999) who pointed out that Shulman's original conception of PCK was indeed topic specific. This term TSPCK emphasizes Shulman's original concern about the absence of subject matter in research on

pedagogy. Mavhunga and Rollnick (2013) argues that although there is general agreement about the topic-specific nature of PCK and its implementation in teacher education programmes, there is limited literature on it.

In their study of investigating improvement of PCK of Chemical Equilibrium in Pre-service Teachers in Johannesburg, South Africa, Mavhunga and Rollnick (2013) sought to showcase the development of PCK within a specific topic, in a teacher preparation programme using chemical equilibrium as a topic. Through mixed methods, an intervention was conducted with 16 physical science pre-service teachers to determine how the improvement of the quality of PCK within Chemical Equilibrium is influenced by the five content-specific components. The study also aimed at exploring strategies to explicitly enhance the quality of PCK and highlighting the practical value of implementing topic-specific PCK in the South African context. Mavhunga and Rollnick (2013) re-conceptualized PCK to reveal five components that make it topic specific PCK due to their orientation to Subject matter knowledge as: (a) learner prior knowledge, which includes common learner misconceptions known in a topic; (b) curricular saliency, which refers to the identification of the most important meaning of major concepts of a topic, without which understanding of the topic would be difficult for learners and also includes the knowledge to logically sequence the learning, and the knowledge of pre-concepts needed prior to teaching a topic; (c) what is difficult to understand, which refers to gate keeping concepts which are difficult to understand often because they cause conflict with previously established understanding; (d) representations, which refers to a combination of representations at macro, symbol and sub microscopic levels that may be employed to support an explanation; and, lastly (e) conceptual teaching strategies, which refers to teaching strategies derived from the considerations made from the other four components and excludes general teaching methodologies. Gess-Newsome (2015), asserts that these components reveal the level of understanding of the knowledge needed for teaching a topic. One major finding of the study was that explicit discussions may significantly improve the quality of Topic-Specific PCK, as a theoretical construct located within a topic. The implication of this finding was that there is a reciprocal relationship, between PCK and pedagogical transformations evident in the significant improvement in the understanding of content knowledge in the topic.

Understanding for teaching that is topic-specific is generated when a particular element of Subject Matter Knowledge (SMK) is thought about and reasoned through these content-specific

components of a topic. A model which linked classroom activities with teacher's PCK and the contributing fundamental knowledge bases was developed by Davidowitz and Rollnick (2011). This model highlighted four teacher knowledge domains which have their origin in the model for PCK suggested by Grossman (1990), namely: (i) knowledge of context, (ii) knowledge of students, (iii) SMK and (iv) PK. There is a strong similarity between PCK components identified by Magnusson et al (1999) and this model.

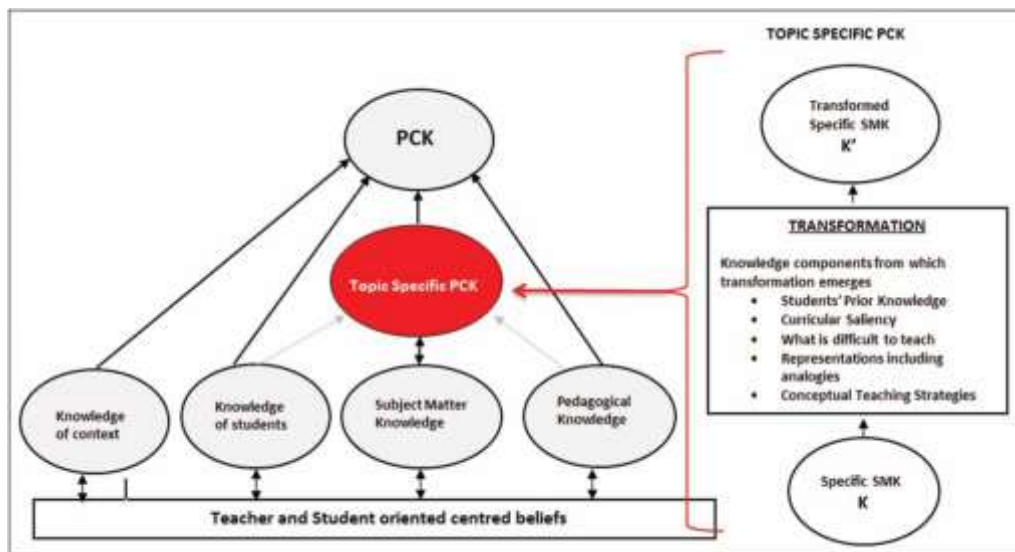


Figure 2.3: A model for Topic-Specific PCK (adapted from Mavhunga & Rollnick, 2013)

In this study, through a qualitative case study which is not similar to Mavhunga and Rollnick (2013), the extent to which these five impact on the teachers' PCK of electricity were investigated through classroom observations, semi-structured interviews and workshops for four (4) Natural Science teachers. This study was to establish if similar or different findings or new findings altogether were elicited by the teachers in the study sample in their teaching and learning of the topic – Electricity.

2.3 Subject Matter Knowledge (SMK)

Mavhunga and Rollnick (2013) highlights that in 1986, Lee Shulman pointed out to the inadequacies regarding the teachers' knowledge base as comprised only of subject matter knowledge (SMK) and pedagogical knowledge (PK). Shulman (1986) further argued for the interrelatedness of the two categories and highlighted that a teacher should have specialised knowledge in specific

subject content for them to be labelled as an expert. Magnusson et al (1999) corroborates that the dependence of subject matter knowledge on the development of pedagogical content knowledge. According to Wood (2016) for teachers to be able to teach and promote learning by students they must have specific knowledge of a subject. PCK itself summarises a teacher's knowledge base, so does not exist as a separate type of knowledge however, in a transformative model, SMK is a separate component. Cofré et al. (2015) argued that in the context of science, to develop appropriate SMK for teaching a variety of science methods and practicums are important.

Ndlovu, Amin and Samuel (2017) in their study examined the subject matter knowledge possessed by pre-service mathematics teachers in KwaZulu Natal province of South Africa. The study involved 59 pre-service teachers that were purposively selected, and their SMK was investigated through a competency test and unstructured interviews. The results revealed gaps in the teachers' SMK with the main challenge being their inability to analyse and interpret learners' errors for diagnostic purposes. Internationally, Nixon, Hill and Loft (2017) carried out a longitudinal study in which they explored the development of new secondary science teachers' SMK in their first five years in the USA. The findings showed that the chemistry teachers' SMK did not change significantly from their 1st year of teaching to their 5th year of teaching. It cannot be concluded that the findings would apply in the South African context due to the different schooling environment as well as curriculum.

In this study, the teachers' subject matter knowledge as a major component of teacher expertise, one that underpins the ways in which teachers display their knowledge of principles, help children to develop understanding of the content of Science, as well as their ability to inquire was explored through a qualitative case study. This was done to establish if similar findings to the ones by Ndlovu et al (2017) as well as Nixon et al (2017) were arrived at.

2.4 Teaching and learning of natural science in South Africa

According to Stephen (2018), South Africa has undergone a series of curriculum changes, has a wide range of school types as well as stakeholders. There are several factors; political, historical, social, religious as well as economic that contributes to the difference in the quality of education delivered to the learners under the current curriculum, just like in any other curriculum. According to Tshiredo (2013), education in South Africa has always been faced with many challenges since the early years of apartheid until to date. The challenges include resistance, inadequate teachers'

knowledge and skills, educators' development and training, resources, disparities between rural and urban schools and lack of support and monitoring. All these challenges might be the factors affecting adversely the teaching and learning of science in South Africa. Christie (1991) puts more emphasis on the inequalities of social class and differences between rural and urban schools pointing out that they still persist. Most schools in rural areas are still inadequately resourced as compared to schools in urban areas which enjoy abundance of learning resources and suitable infrastructure (Tshiredo, 2013). In this study, the curriculum in South Africa in general as well as the Grade 9 Natural Science curriculum were discussed to give the context in which the teachers operate, the expectations as well as conditions which might affect their PCK of the topic - electricity. As researcher, I believe that problems in curriculum change effort manifest themselves in gaps between the intended curriculum (policies) and the implemented (real life in school and classroom practices), and the attained curriculum (learner experiences and outcomes).

2.4.1 Curriculum in South Africa

South African education system has undergone a series of curriculum changes since the dawn of democracy. This is because education is constantly changing as a professional field due to different factors which include political, social and economic change within a country. This is not something unique to South Africa as it occurs internationally on an ongoing basis and reflects changes in the society (Moodley, 2013). The curriculum (syllabus) revision process of late 1994, according to Jansen (2001,p.143), “was presented as an attempt to alter in the short term the most glaring racist, sexist and outdated content inherited from the apartheid syllabi, which were still widely used in the aftermath of the first post-apartheid elections in April of the same year”. This had led to many curriculum shifts, first, Curriculum 2005 (C2005) was introduced, which was followed by the National Curriculum Statement (NCS). Furthermore, challenges in the implementation of the NCS resulted in another review in 2009 and now recently Curriculum and Assessment Policy Statement (CAPS). However, their aim was not to completely eradicate the Revised National Curriculum Statement. They use the RNCS as a starting point by reducing what was not effective and putting what they think will address the challenges on curriculum implementation. (DoE, 2011).

All these were depending on the political state at the time. The Constitution of South Africa (Act No. 108 of 1996) provides the basis for the transformation of the curriculum in South Africa. According to HSRC, 2009 in Moodley (2013), the aims for the curriculum change as stated in the preamble, were amongst others to heal the divisions of the past and establish a society based on

democratic values, social justice and fundamental human rights, among other things. However, Moodley (2013) further argues that the vision of the DoE with regards to the curriculum change was not necessarily that of educators who are to implement it.

According to the DBE, CAPS is a document in which curriculum documents for all the subjects have been reorganised in such a way that they will minimise workload for the teachers and enhance the implementation (DBE, 2011). There is new terminology again for the teachers and learners to acquaint themselves with. Learning areas are now referred to as subjects, learning outcomes and assessment standards have been replaced with specific content skills to be achieved in the form of knowledge and skills, and there is reduced paperwork with which teachers need to deal (DBE, 2011).

2.4.2 Grade 9 Natural Science Curriculum

Orsntein and Hunkins (2009) argue that curriculum changes should bring a difference in the way learners attain their education and to bring into reality the anticipated changes. The South African Department of Education asserts that the main purpose of the Natural Sciences (Grades7-9) is to promote scientific literacy which encompasses the prevailing international definitions including the development and use of science process skills in a variety of settings, the development and application of scientific knowledge and understanding, and the appreciation of the relationships and responsibilities between science, society and the environment (DoE, 2002).

CAPS document for Natural Sciences grade 7-9, is divided into four sections.

- Section 1 deals with Introduction to CAPS, covering background, overview, general aims of the South African Curriculum,
- Section 2 deals with Introduction to Natural Sciences
- Section 3 deals with Senior phase Natural Sciences Content and Concepts, which is generally known as the Annual Teaching Plan (ATP) and outlines all topics to be taught in each grade, each term
- Section 4 deals with assessment, recording and reporting

Natural Sciences is a very complex subject, based on its organisation, the fact that it consists of four different subjects, all brought together to form 1 subject, Natural Sciences. The changes made

in this subject, Natural Sciences, focused only on the structure of the subject, the sequencing and general organisation of the subject. It is divided into four strands namely;

- (i) life and living,
- (ii) Matter and materials,
- (iii) Energy and change as well as
- (iv) planet earth and beyond.

Assessment in NS has not changed much over the years and is both formal and informal. Assessment includes classworks, tests, examinations, practical work and projects. The learners are deemed competent if they can achieve at level 2 (30-39%) in NS. Tshiredo (2013) reports that looking specifically at the changes that took place in (CAPS) documents; one can anticipate a different impact of curriculum change in teaching and learning of science in schools. In the recent policy (CAPS) Curriculum and Assessment Policy Statement, the purpose of studying science is biased on the following taken from the DoE (2011:12-13)

- The development of science knowledge and understanding.
- The development of science process skills (scientific investigation).
- The development of an understanding of sciences' role in society

Beni et al., (2012) report that teachers are expected to teach natural science in an integrated life skills programme by focusing on an inquiry-based, problem-solving approach. The extent, to which they are able to do this, depends on their understanding of the curriculum which, in turn, might influence the way they implement the curriculum. Rogan and Grayson (2003) maintain that for curriculum change to occur, both the 'why' (the need for curriculum change) and the 'how' (issues pertaining to the implementation) must be addressed. Gray and Bryce (2006) argue that teachers need to be capacitated in teaching science in order to ensure that they are able to implement changes made to the curriculum and able to sustain them. In this study, the teachers' ability to implement the curriculum as outlined above in Grade 9 Natural sciences classroom was investigated.

2.5 Effective teaching of Natural Science

Effective Science teaching is the gateway to attainment of scientific and technological greatness (Lekhu, 2013). Lekhu further states that the teaching and learning of Science has always been, and

continues to be, clouded by problems that impede the effective delivery of the subject to learners. These factors can either be teacher-related factors or general school factors that have a negative influence on the learning environment. It is important to understand how teachers teach Natural Sciences and different factors affecting them. More often than not, the teacher's knowledge gained from his/her learning experiences, opinions about good teaching and beliefs about the purposes for the subject affect his/her effectiveness. Successful teaching requires that teachers make sense of their students' ideas and respond to unexpected events in the classroom environment (Beni, et al, 2012).

There are a number of factors, which make the teaching of Science ineffective in classrooms. These include lack of a strong background in Science content, poor preparation in Science content, poor instructional leadership, inadequate facilities and equipment, and the teacher's attitude (De Laat & Watters, 1995; Halim & Meerah, 2002). Teachers' are expected to teach Natural sciences in an integrated life skills programme by focusing on an inquiry-based, problem-solving approach. The extent, to which they are able to do this, depends on their understanding of the curriculum which, in turn, might influence the way they implement the curriculum. Rogan and Grayson (2003) maintain that for curriculum change to occur, both the 'why' (the need for curriculum change) and the 'how' (issues pertaining to the implementation) must be addressed. In this study, the teachers' effectiveness to teach science was investigated looking at some of the factors that affect teaching and learning as discussed below.

2.5.1 Electricity as a topic

Moodley (2013) states that the CAPS document (2011) shows the progression of the electricity concept by introducing energy first in Grade 8 and energy systems and conversions in Grade 9. In Grade 10, learners are taught the concept of electrostatics, charge, potential difference and current in sequential order. This is an indication that electricity develops from lower grades and becomes complex at a secondary and tertiary level. According to CAPS document, the topic of electricity is to be taught in term 3 and falls under the strand: energy and change. According to Beaty (1996), the most used definition of electricity taught to learners is that it is the flowing motion of electric charge. It is from this that we could say that there is an assumption, for example, the existence of charges, and that they can move together in a flowing motion called a current. Moodley (2013), states that electricity is explained to children at lower levels in terms of static

electricity and current electricity. Static electricity is caused by the transfer of charges that can be observed as sparks when objects are rubbed together. Later on, learners are taught that current electricity results when a battery causes an “electrical pressure” in a closed circuit. This lays the foundation for conceptual understanding of a potential difference that must be followed up in higher grades as “energy transfer per unit charge.”

Although the topic is spread over a period of 6 weeks, teachers never get enough time to teach it since this period coincides with the writing of grade 12 preparatory examinations.

2.5.2 Factors affecting the teaching of electricity in South Africa

Reality is that in most South African classrooms teaching is teacher-centred with an emphasis on lecturing, question and answer exchange, written exercises and tests and very few learner discussions and practicals (Menoe, 2005). Menoe (2005) further argues that the emphasis is not on problem solving and creativity but rather on memorization and recall. Students’ involvement is minimal, they rarely ask questions and their incorrect answers are often ignored rather than corrected. These anomalies are easily confirmed during classroom visits. Various explanations are given for these practices and according to (Howie, 2002; Motswiri 2004) they include the following:

- Teachers’ lack of mastery of subject matter content and basic teaching skills
- Lack of material facilities and large class sizes
- Language problems for both teachers and learners
- Examinations have a dominant influence on classroom instruction
- Tension between African culture (tradition, values), life outside the school environment and culture of inquiry required in the classroom.

These practices show that for a learner-centred approach to be effected, the practice and context of teaching would need to be changed. Most teachers in developing and developed countries are still grappling with how to successfully implement learner-centred teaching practices (Menoe, 2005). For the effective teaching of electricity to be attained, the contextual, systematic, political, social factors should be addressed.

2.5.3 Teachers' content and pedagogical content knowledge

Teachers' content and pedagogical content knowledge entails subject specialization, that is, knowledge of the discipline that a teacher is qualified to teach. Guerriero (2016) explains pedagogical knowledge as specialized knowledge of teachers for creating effective teaching and learning environments for all students. International and local researchers agree that content and pedagogical content knowledge is necessary but emphasize that it is not sufficient (De Clercq & Shalem, 2012). Lekhu (2013) reports the role of a teacher is to impart knowledge to the learners so that they acquire desirable skills, abilities, knowledge and other competencies, which would help them in their later life. To achieve this, the teachers should be well-versed in their teaching subjects and be ready to teach within the level of their learners (Abuseji, 2007).

Hlaing and Maw (2016) assert that all issues of students' learning, classroom management, lesson plan development and implementation, and student evaluation are encompassed in a teacher's pedagogical knowledge. They further argue that pedagogical knowledge includes knowledge about techniques or methods to be used in the classroom; the nature of the target audience; and strategies for evaluating student understanding. A teacher with deep pedagogical knowledge understands how students construct knowledge, acquire skills and develop habits of mind and positive dispositions towards learning (Koehler, 2011).

Moodley (2013) argues that information about electric circuits is not easy to provide to learners in a manner that is comprehensible. He further states that learners may find difficulty in mathematical manipulation for simple calculations at Grade 9 level. In order for learners to answer more complex circuit questions, they will need to apply their numerical understanding. Gunstone (2008) states that in science classrooms more focus is on calculations rather than conceptual understanding and practical work. Based on the above studies, teachers' content and pedagogical content knowledge of electricity was investigated in this study.

2.5.4 The quality of Natural Science teachers

"The quality of education hinges on the quality of teaching that happens in the classroom, reinforcing the idea that quality teachers make up for the deficiencies in the curriculum and in educational resources" (Lekhu, 2013:39). Dangara (2015) asserts that the quality of teachers employed determines the success and quality of any education system. Teachers' characteristics, such as qualifications and experience, are factors which relate to learners' performance; it also affects their learning (Omolar, 2008). The most valuable resources for quality teaching in the

school are quality teachers. There is an increase in learner achievement when teachers are of good quality and competent.

According to the study conducted by Burton (2006-2007), it declared Natural Sciences teachers as underqualified and incompetent, hence teachers had to attend contact sessions, in a wake to close down the content gap identified. Burton's study further revealed that most of the teachers, as they interacted with the researcher, they declared that they left some of the topics they did not understand themselves. In most secondary schools, the focus is more on producing good results at Grade 12 classes rather than Grade 9 classes. As a result of the pressure to perform better at grade 12, the most qualified and experienced teacher is allocated senior classes and less qualified teachers to the lower grades. Actually, this practice is common even in developed countries for some time now (Hallam & Ireson, 2001).

2.5.5 Teachers' experience

Moodley (2013) assert that the teachers' experiences and beliefs play a vital role in the manner they teach. Teachers with fewer years of experience in the school system need the guidance of experienced more knowledgeable supervisors and subject advisors. This is very helpful to develop the skills and capabilities that are required to guide the learning process (Madziyire, 2010). Teachers have a role in determining what is needed or what works best with learners (Eslami & Fatahi, 2008). This includes lesson plans, unit plans and year plans and a certain level of experience is needed to effectively execute this. All developmental and planning activities need guidance and direction at every stage (Olulube & Major, 2014). Teachers who are more experienced in the teaching of science often do not struggle in the selection of strategies and resources, and in monitoring and evaluating those strategies. These teachers are able to employ different assessment strategies, taking into cognizance learners' barriers to learning, to achieve maximum curriculum coverage.

Nzoka and Orodho (2014) argue that teachers should be experts in the alignment of curriculum to the topics and assessment, without adequate experience in the subject this often proves to be difficult. Educational level and experience of teachers improve learners' trust towards them and inculcate the love for Natural sciences as a subject. Recently there has been an exodus of teachers from the system due to various factors. This has led to schools especially rural ones depending on

new teachers, fresh graduates from the university. Most of these teachers are young and not confident enough to teach science.

2.5.6 Teaching and learning resources

There have been a number of studies to investigate the influence of teaching and learning resources on effective curriculum delivery (Coleman & Anderson, 2001; Orodho, 2013; Orodho & Glennonn, 2003). Most schools in South Africa especially those in previously disadvantaged areas are still experiencing shortages when it comes to resources and this has a negative impact on the quality of teaching and learning. However, there are some schools with better resources and this enables them to perform better (Rogan & Grayson, 2003).

Bizimana and Orodho (2014) found that unavailability and inadequacy of learning resources impacted negatively on the teachers' effectiveness and attainment of good results. Most teachers rely on textbooks to teach science since they are often the only available resource in the school. These textbooks enable learners to study at a later stage and improve on their academic progress. Learners in some schools share these textbooks, which mean they can only learn when it's their turn to use the textbook.

The North West Department of Education (NWDoE) has committed to match resource availability with resource requirements, increase infrastructure, provide equipment, provide relevant textbooks, equip Science labs in schools to meet curricula demands, expand education facilities specifically laboratories and equipment for priority subjects. Matsemela (2016) highlights that the department has established a Mathematics, Science and Technology Education (MSTE) unit to assist in provision of science resources to schools, including mobile laboratories as well as additional teachers to such schools. Teachers link ineffective teaching and learning, ineffective classroom management and content delivery to this scarcity of resources. It not the purpose of this study to focus on the challenges faced by the department of education but to investigate the teachers' ability to effectively use the limited resources at their schools.

2.5.7 Practical work

According to Millar (2011) the term 'practical work' refers to an activity in which learners are involved in manipulating and/or observing real objects and materials. Practical work is widely and

frequently used in the teaching of science since it can be both affective and effective in terms of students' learning and enjoyment of science. Moodley (2013) reported that some teachers prefer demonstrations to practical work because it is an easy way for them to maintain control in the classroom. This preference seems to be the most prevalent in most South African schools since the classrooms are often overcrowded and learners are rowdy.

The unavailability of resources in schools such as laboratories, science equipment makes it difficult to conduct practical work as a strategy (Ajileye, 2006). Although teachers often request the learners to bring basic equipment like batteries, copper wires, light bulbs and other material for the construction of electric cells, they usually do not succeed. For the learners' performance in electricity to improve, provision of resources to schools by the government should be prioritised. In this study, the teachers' ability to effectively conduct practical experiments as a teaching strategy will be explored.

2.5.8 Misconceptions in electricity

Literature is replete with studies that focus on learners' ideas, beliefs and scientific misconceptions. According to Dudu (2016) the phrase *misconceptions* is often used to refer to these ideas that are not in consonance with accepted scientific ideas. Both Science teachers and learners hold *misconceptions*: conceptual and propositional knowledge that is inconsistent with or different from the scientific consensus and is unable to adequately explain observable scientific phenomena.

According to Piaget, children search for meaning as they interrelate with their surroundings and utilize such encounters to test and modify existing schemas (Eggen & Kauchak, 2007). Unfortunately, some of the meanings obtained from these experiences inadvertently promote the development of alternative conceptions. According to the National Research Council (1997), misconceptions can be broadly classified into five types, and these are: *preconceived notions*, *non-scientific beliefs*, *conceptual misunderstanding*, *vernacular misconceptions* and *factual misconceptions*. Mackay and Hobden (2012) reported that to gain insight into the learners' misconceptions regarding basic circuit electricity, their circuit and wiring diagrams are useful. Moodley (2013) reports that a number of studies were conducted to find common misconceptions in circuits by learners and it was found the same misconceptions existed (Table 2.1).

Gaigher (2014) argues that the student's age plays a role in the ability to deal with preconceived ideas for the basic electric circuits. He contends that generally the misconceptions decrease with increasing student age. More often than not misconceptions are not easy to address as a result conflict teaching is important. In this study, the teachers' ability to recognise, analyse and interpret learners' misconceptions according to Moodley (2013) was investigated through classroom observations and semi-structured interviews.

2.6 Teachers' beliefs

According to Anderson (2007), teachers are faced with a number of dilemmas many of which are rooted in their beliefs and values when dealing with new pedagogical approaches to education. Philipp (2007) refers to beliefs as psychologically held convictions by people. Binns and Popp (2013) argue that teachers' beliefs, values and views regarding knowledge influence their teaching. Sikko, Lyngved and Pepin (2012) argue that teachers' beliefs about science, beliefs about the nature of science, beliefs about teaching and learning influence the way they choose different strategies to use in their teaching.

In a study by Ramnarain and Hlatwayo (2018), an investigation was made on Grade 10 Physical Sciences teachers' beliefs and attitudes about inquiry-based learning. The study was carried out in Mpumalanga, South Africa using mixed methods research design. The results indicated that sampled teachers had positive beliefs towards inquiry-based learning. Contrary to their beliefs on IBL, their approach was teacher-based, and learners were given limited opportunity to design inquiries. However, a positive attitude was observed when teachers expressed the desire to create more learning opportunities in future for learners to engage in. Taking leaf from Ramnarain and Hlatwayo (2018), in this study teachers' beliefs and attitudes about teaching of the topic - Electricity was investigated utilising a qualitative case study design. Internationally, Chan (2010) conducted a study in Hong Kong on primary school teachers' beliefs about inquiry-based teaching and learning. The results revealed that teachers had positive beliefs but interestingly, this study found out that their beliefs did not influence their choice of pedagogical strategies nor influence their classroom practices. This study seeks to establish whether the results by Chan (2010) are corroborated by the sampled South African teachers or totally differ.

Table 2.1: Comparison of well-known misconceptions and scientific model (adapted from Moodley, 2013)

(i) Misconception/Model	(ii) Scientific Model
(iii) The unipolar model or sink model : Learners believe that only one wire connected to a battery is needed for the circuit to work (Chambers & Andre, 1997).	(iv) There needs to be two wires to connect the two poles of the battery to the two sides of the resistor. In one wire current flows from the battery to the resistor and in the second wire, current flows from the resistor back to the battery.
(v) The attenuation model : Learners believe that less current returns to the battery. They think each device consumes some of the current passing through it (Shipstone, 1988).	(vi) Current is not consumed by the electric devices: all current returns to the battery. It is energy, not current, that is transferred to the device that causes it to work.
(vii) The sharing current model : Learners believe that the current is shared by the devices in the circuit, and that less current return to the battery (Shipstone, 1988).	(viii) Current in a series circuit is the same throughout the circuit, whereas in parallel circuits, current branches and re-joins again such that all current is conserved.
(ix) The sequential model : Learners believe that a change in the circuit will affect current in parts of the circuit that are located ‘ahead’ the change, but not in parts located ‘behind’ the change (Dupin & Joshua, 1987).	(x) Any change made in a circuit affects the circuit as a whole. For example, if a resistor is added, the current will decrease throughout the entire circuit.
(xi) The clashing current model : Learners believe that current flows from both poles of the battery in opposite directions to the resistor. These currents are seen as a positive and a negative current which clash in the resistor such that the clash creates energy in the resistor (xii) (Chambers & Andre, 1997).	(xiii) Current in a circuit flows in one direction. Conventionally, current flows from the positive terminal of a cell, around the circuit to the negative terminal. The current is made up of moving charges carrying electrical potential energy. When the charges collide with atoms in the resistor, the energy is transferred to the resistor.
(xiv) The short circuit model : Learners believe that wires in a circuit with no electrical devices can be ignored when analysing the circuit (Fredette & Clement, 1981).	(xv) A short circuit is a path without resistance that bypasses resistors. If a battery is shorted, other devices will receive no current while the current in the wire and battery will become very large because current takes the way of least resistance. The wires will become very hot and may melt, and the battery will overheat and become exhausted.
(xvi) The power supply misconception : Learners believe that the power supply provides constant current regardless of how the circuit is changed (Dupin & Joshua, 1987).	(xvii) An ideal battery supplies a constant voltage, not a constant current. The current is the result of the combined effect of the voltage and the effective resistance of the circuit. This means that changing a device in a circuit changes the current while the voltage is unchanged.
(xviii) The parallel circuit misconception : Learners believe that if the numbers of resistors in parallel are increased, the total resistance will also increase (Cohen, Eylon & Ganiel, 1983).	(xix) Connecting more resistors in parallel reduces the total resistance because it creates more pathways for current to flow in the circuit.

2.7 Teachers' pedagogical orientations

A number of researchers have undertaken studies focusing on the interactions between science teaching orientations (STO) and teacher beliefs and how they both affect a teacher's classroom practice (Volkmann et al., 2005; Park & Oliver, 2008; Park & Chen, 2012; Aydin et al., 2015). Magnusson et al. (1999), refer to teachers' knowledge and beliefs about the purposes and goals of teaching science as teacher orientations. They further argue that teacher orientations are important since they guide the teacher on the kind of learning experiences and activities for a particular lesson. Mavuru and Ramnarain (2017) assert that there are various conceptions of science teachers' orientations about science and science teaching and learning.

Mavuru and Ramnarain (2017) investigated how social context relate to teacher orientations in Grade 9 Natural Science teachers at township schools in South Africa. The study employed a qualitative case-study research design, with purposeful sampling of three Grade 9 Natural Science teachers. They used the nine pedagogical orientations outlined below as proposed by Magnusson et al. (1999) to analyse teachers' orientations in the study. The proposed nine different orientations to science teaching used are:

- Process, where teachers engage learners in activities to develop thinking process
- Academic rigour, where teachers challenge learners with difficult problems and activities
- Didactical teaching through lecture or discussion, and questions directed to learners
- Conceptual change, where teachers engage learners in discussion and debate so that learners can construct valid knowledge claims
- Activity-driven teaching, where learners are involved in hands-on activities
- Discovery, where learners explore their thought process and interest
- Project-based science, where learners engage in investigative work to generate new information
- Guided inquiry, and open inquiry where learners are involved in identifying problems and solving them through investigations with and without teachers' guidance respectively.

The findings of the study are that pedagogical orientations are influenced by learners' socio-cultural practices, experiences and beliefs. A change in the teachers' views about the goals and purposes of science teaching was observed. A qualitative case study was also conducted in Turkey by Demirdöğen (2016) who investigated how science teaching orientation and pedagogical content knowledge interact in pre-service teachers. Three major themes were revealed upon comparing how the teachers' science orientation interacted with other components of PCK: (1) one's purpose

for science teaching determines the PCK component(s) with which it interacts, (2) a teacher's beliefs about the nature of science do not directly interact with his/her PCK, unless those beliefs relate directly to the purposes of teaching science, and (3) beliefs about science teaching and learning mostly interact with knowledge of instructional strategies. The three themes were developed into a model for future use when investigating teachers' science orientations. One of key findings from Demirdögen's (2016) work is that student-teachers' nature of science beliefs only interrelated with their PCK provided they were specifically linked to their goals of science teaching.

In this study, similar methodological approaches utilised by Mavuru and Ramnarain (2017) were employed to investigate teachers' orientations to science teaching. The only difference was the environmental context since this study focuses on teachers in rural areas. Figure 2.4 shows the STO concept map used in this study.

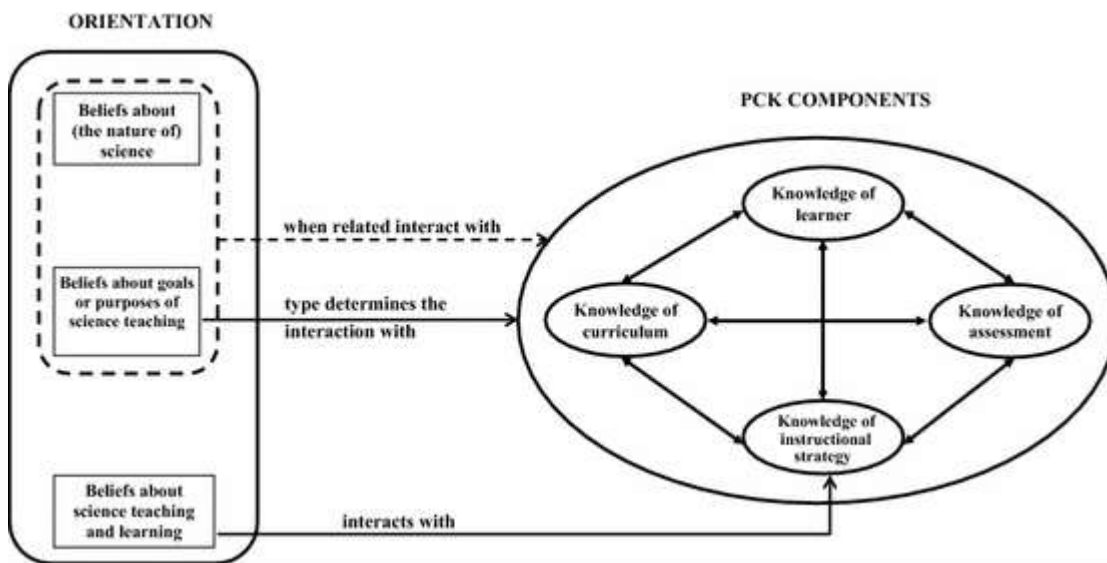


Figure 2.4: Concept map of STO and PCK (Adapted from Demirdögen (2016))

In this study, Demirdögen's (2016) model was used during classroom observations and workshops. This is because it encapsulates all the PCK components that were investigated.

2.8 Teachers' Professional Development

Pretorius, De Beer and Lautenbach (2014) argue that there is a need for professional development to address science teachers' learning of science. Pretorius et al. (2014) also indicate that professional development interventions in South Africa do not always address teachers' needs or necessarily result in better realisation of outcomes in science. There is often a mismatch between the trainings conducted for the teachers and what the teachers need to be empowered on. The teachers are never asked what exactly they struggle to teach, what they think should be done to assist them, how that should be done and who do they think is better placed to do that. Darling-Hammond et al. (2017) refers to effective professional development as changes in teacher practices and student performance as a result of a professional intervention. It implies that if teacher professional development is properly planned and executed, it has the potential to promote sustainable lifelong learning that will in turn enhance learner success. Studies have shown that the success of teacher professional development is meaningful if it is implanted in the teachers' subject specializations (Darling-Hammond, Chung, Andree & Richardson, 2009).

There are two main types of teacher professional development, and these are classroom observations and workshops. Halim, Wahid and Halim (2018) define classroom observation as "a method of evaluating and recording specific information about what is going on within a classroom". It means that classroom observation involves the measurement and recording of classroom behaviours and associated events. In general, classroom observations are ideally aimed at improving the quality of instruction and enhancing the effectiveness of teaching. It goes without saying that because of their inherent nature, classroom observations bring along some uneasiness, anxiety and emotions especially on the teacher being observed. To avoid unnecessary contestations that may arise due the observations, it is crucial to thoroughly plan for and ensure that the classroom observations are as objective as is possible.

There are numerous classroom observation methods that have been developed and they utilize a combination of propositions that they can all be generally grouped as either unstructured or structured (Noguera, 2018). Unstructured observations are analytical in nature and generally capture what the observer believes to be of importance and thus are fairly subjective. On the other hand, structured observations are systematic and primarily anchored on some existing predefined categories and hence they are apparently objective since the observer's inferences and judgements are limited (Noguera, 2018). In summary, classroom observations may be undertaken for a variety

of reasons and may be classified according to their main goal that is in turn related to their contextual setup.

A workshop is an instructional programme designed to teach or share knowledge, skills, techniques or ideas that will empower participants to effectively execute their duties. In education, traditional workshops are normally conducted over a short period of time and typically last over a few hours to a couple of days. Several researchers have often lambasted traditional teacher development workshops as fragmented, short and divorced from authentic classroom situations (Ball & Cohen, 1999; Feiman-Nemser, 2001; Villegas-Reimers, 2003). They argue that the workshops appear to yield nothing meaningful since they are unlikely to improve the teaching prowess of the participants. To address the aforementioned concerns raised by several scholars with regards to the ineffectiveness of the traditional teacher development workshops, it is important to thoroughly plan for such activities so that meaningful gains are realised from their execution.

According to Darling-Hammond et al. (2017), there are seven important elements for effective professional development, and these are:

- **Focus on content.** Effective PD should be subject-specific and geared towards honing specific instructional strategies.
- **Creation of opportunities for active learning.** Participants should be given opportunities to employ their prior knowledge and experiences to apply newly learnt material to solve real-life problems.
- **Support work-embedded collaboration.** PD should aid teachers in developing peer observation strategies, communication protocols, co-teaching models, and more.
- **Model best practices.** Effective PD should promote modelling and application skills instead of the traditional and archaic lecture-based professional development.
- **Coach and support.** Instructional coaching should take a pivotal role in creating avenues for continuing observation, feedback, reflection, and enhanced practice.
- **Incorporate feedback and reflective practice.** Participants should be provided with informative and timely feedback. The educators should also be provided with time for reflection and action on the feedback given.
- **Sustained duration.** Once-off PD sessions are generally not effective, thus sustainable

workshops should be planned over a period of time and should be constantly backed by dynamic support mechanisms.

Figure 2.5 depicts a PD model that promotes learner achievement, and the model is heavily inspired by works of Cohen and Hill (2000), Fishman, Marx, Best & Tal (2003) and Guskey and Sparks (2004).

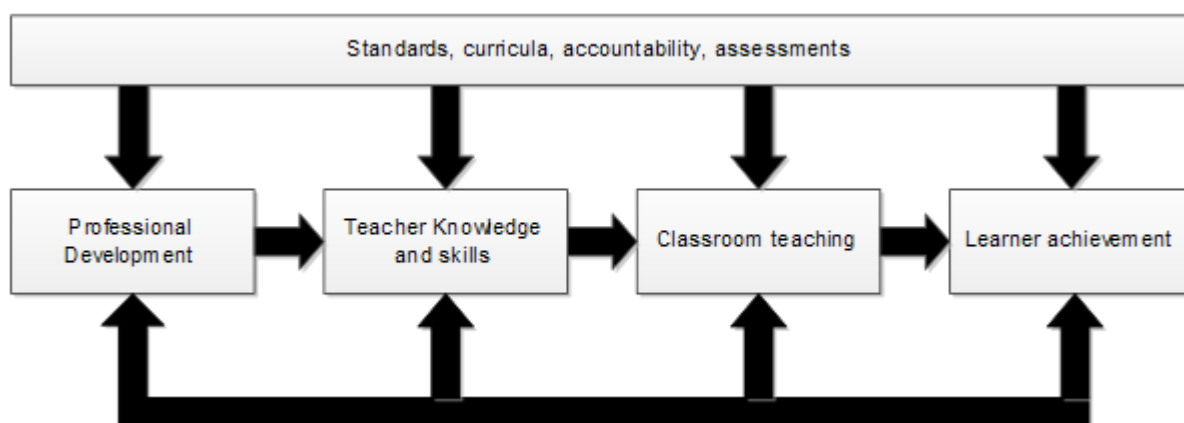


Figure 2.5: How professional development affects learner achievement (adapted from Yoon *et al.* 2007)

Dudu (2016) argues that there is an extensive body of research on how effective change occurs in educational settings and designers of Professional Development (PD) can be guided by it. Dudu (2016) conducted a study to investigate how the teachers' content knowledge gaps, didactics and pedagogy to improve teacher effectiveness were impacted upon by a support and guidance professional development intervention programme. He employed a case study research design which utilised a one group pre-test post-test quasi-experimental research design and 51 Grade 12 Life Science teachers at various Dinaledi schools from the North-West province of South Africa participated. The study's finding was that professional development intervention carried out addressed content knowledge gaps, didactics and pedagogy to improve teacher effectiveness to a larger extent. The results revealed that teachers have difficulties in certain Life Science concepts, however their misconceptions were identified, and teaching strategies were used to address the teachers' content knowledge regarding the topics. In this study, contrary to the study by Dudu (2016), a qualitative multiple case study research design was employed to examine the impact of professional development intervention on the teachers' PCK of the topic - Electricity topic. The ever-changing environment with which students have to contend as they learn puts added pressure on the teachers and education authorities on how to adapt teacher professional development (TPD)

in order to meet these needs (Phoshoko, 2015). The two main types of teacher professional development are classroom observations and workshops as discussed above were also utilised in this study collect data on Grade 9 Natural Science teachers.

2.9 Teachers' professional growth

A major question in teacher change literature relates to the issue of whether and how changes in knowledge, beliefs, and attitudes relate to changes in teacher practice (Wongsopawiro et al., 2017). According to Wongsopawiro et al. (2017), there is an assumption that teacher's teaching practice which often leads to improved students' performance is influenced by changes in the teacher's attributes such as beliefs, attitudes and teaching methodologies. Guskey (1986) asserts that a lesson delivery, administration of assessment, and so on leads to improved teachers' learning. Contrasting the accepted discourse at that time, he proposed a model of teacher change, where a professional development programme could cause changes in a teachers' practice, which in turn could lead to changes in students' learning, and therefore could result in changes in teachers' knowledge, beliefs, and attitudes.

According to Justi and Van Driel (2006), research has revealed that science teachers' content knowledge, curricular knowledge, and pedagogical content knowledge on models and modelling are often incomplete or inadequate. From this perspective, a research project was designed which aimed at the development of beginning science teachers' knowledge in this domain. In this project, the Interconnected Model of Teacher Professional Growth (IMTPG) developed by Clarke and Hollingsworth (2002) was used as the basic framework for the establishment of the relationships between the different data gathered in characterising teachers' knowledge on models and modelling. In order to support teachers' knowledge building, many researchers have recognised that such processes should involve active meaningful learning. Clarke and Hollingsworth argue that teacher professional growth can best be understood in terms of reciprocal relationships between four different domains which encompass teachers' professional world: (1) the Personal Domain, which contains teachers' knowledge, beliefs, and attitudes; (2) the External Domain, which contains external sources of information or stimuli; (3) the Domain of Practice which involves professional experimentation; and (4) the Domain of Consequence, which contains salient outcomes related to classroom practice. According to the model, Clarke and Hollingsworth propound that learning takes place through several routes identified through enactment or

reflection. They refer to “enactment” as implementing the learning or change in belief or embracing new practices. “Reflection” is regarded as vital deliberation that leads to reasoning that triggers change in practice and beliefs. The model also places great emphasis on the identification of the change environment which is essentially the school and its environs. In addition, Clarke and Hollingsworth emphasise the importance of placing significant consideration on the process in which professional learning and growth may materialize in response to external factors such as informal engagements. The model is illustrated in Figure 2.6.

The general practice in South Africa is that, despite the one-day workshops conducted for teachers by Subject Advisors, little professional development is provided for qualified teachers by universities, other than in the form of academic degrees. According to Rollnick and Brodie (2011), there are seven guiding principles for teacher development in South Africa. One of the principles calls for actual school and classroom data to inform teacher learning and development programmes. In this study, this was done in the form of classroom visits. It is important to have first-hand information on how teacher knowledge is transformed in practice before developing any programmes intended to develop their professional growth.

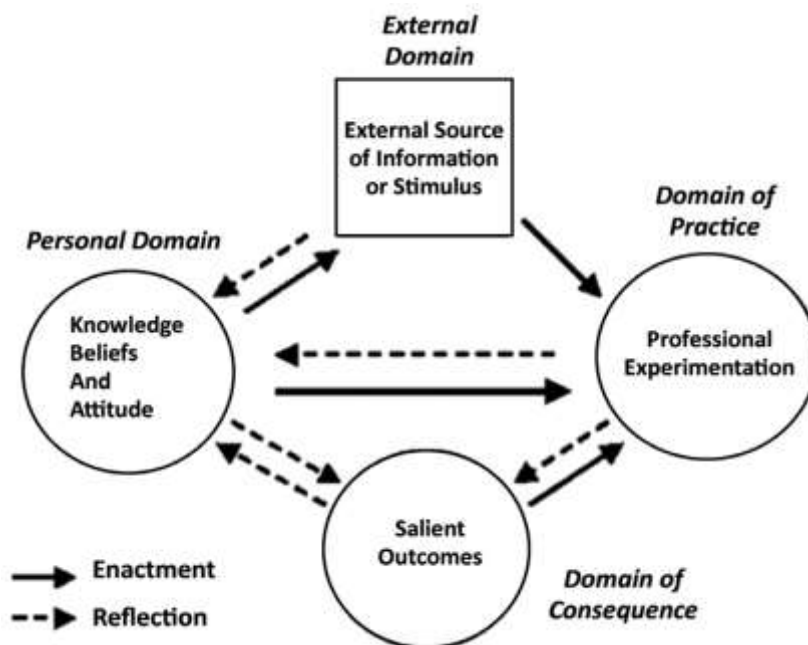


Figure 2.6: Clarke and Hollingsworth’s (2002) IMTPG model

The researcher in this study believes that teachers should be actively involved in a process of knowledge building in order to develop their knowledge and in turn, promote learner success. It is from the aforesaid belief that this study employed and adapted the IMTPG model as the basic framework for the research work and data analysis.

2.10 Teacher change

One of main aims of professional development programmes is to effect meaningful change in teachers' beliefs and attitudes on the presumption that such changes will lead to positive changes in classroom practices and in turn, to learners' enhancement and success. According to Tam (2015), teacher change comprises changes that involve both cognition and action. Teacher cognition essentially relates to teachers' beliefs, knowledge and attitudes in the teaching and learning environment (Ng & Leicht, 2019). Ng and Leicht (2019) further define teacher action as all the activities engaged in by the teacher to deliver teaching. This calls for careful and meticulous planning of professional development activities so that they deviate from the traditional activities that largely emphasized on the importance of content knowledge at the expense of other key PD elements such as collaboration and participants motivation.

2.10.1 Guskey's Model

Guskey's (2002, p.383) teacher change model is described as "a temporal sequence of events from professional development experiences to enduring change in teachers' attitudes and perceptions" (see, Figure 2.7). It therefore implies that teachers' beliefs and attitudes may change if they notice that their learners' performance changes positively as a result of them altering their classroom practice following a PD activity. Guskey's model is a departure from older teacher models in the sense that it comprises four key elements that have unidirectional relationships that are linearly linked. The model clearly contrasts the notion from older models that suggest that change in teacher attitude occurs prior to learner outcomes. It is crucial to note that Guskey contends that teacher professional development is a very complex and challenging affair that requires constant and ongoing support in order to realise meaningful benefit from the activities (Guskey, 2002).

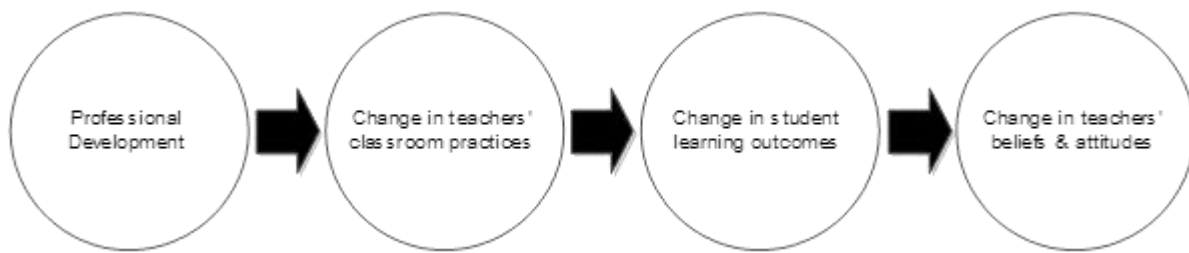


Figure 2.7: Guskey's model of teacher change (Guskey, 2002)

2.10.2 Desimone's Model

Desimone's (2009) model is heavily influenced by the works of early theorists such as Lewin and fairly recent scholars like Guskey. The model is comprised of what she refers to as "core features" of effective PD. Figure 2.8 schematically shows the model with its crucial features. The core features essentially refer to aspects that are generally regarded as crucial by several notable scholars in the field of PD and these features have a direct bearing on the eventual student success that cascades from them. Desimone's model shares a lot of its aspects with Guskey's model, but the two models primarily differ on the ordering and sequence of the important PD elements.

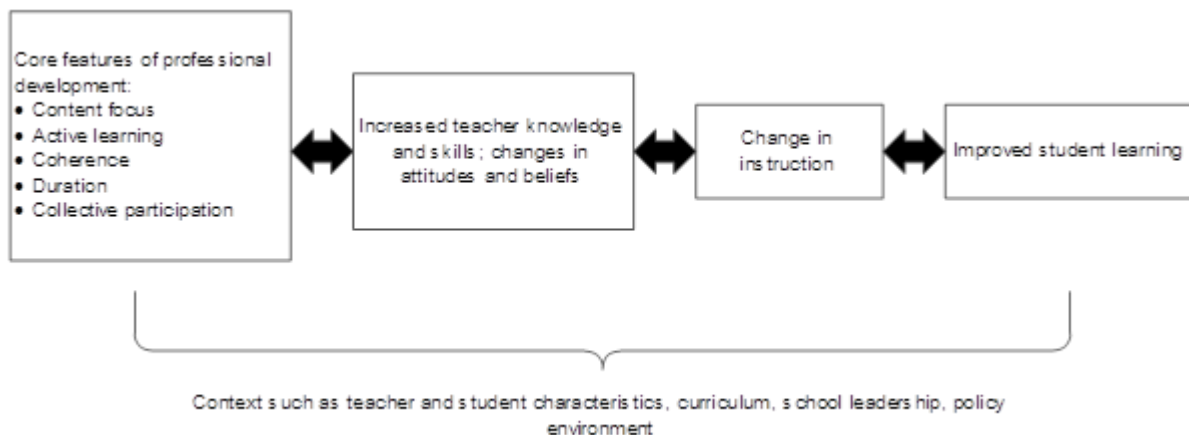


Figure 2.8: Desimone's model (Boylan et al., 2017)

In her model, Desimone (2009) argues that teacher changes in beliefs and knowledge occur prior to their changes in practice (Boylan et al., 2017). However, Desimone posits that the order of the events is not permanent and thus allows flexible interaction between the essential components. Desimone's model proposes the following key features that should characterise all effective PD activities, and these are: content focus, active learning, coherence, duration and collective participation (Boylan et al., 2017).

In this study Guskey's (2002) model of teacher change will be followed since it makes it easy to investigate the teacher change in totality after a professional development intervention is conducted.

2.11 Summary

This study sought to show that there is a unique knowledge base that teachers possess to be able to teach. That knowledge of the subject matter reveals itself in their classroom actions and according to Shulman (1986) is known as pedagogical content knowledge. According to Toerien (2013), the manifestation of PCK in teachers is different and a number of models have been useful in identifying these manifestations of PCK and their relationships with the fundamental knowledge domains. It is important to have experience as well as subject matter knowledge to develop PCK (Kind, 2009). Teachers' development of PCK in teaching is dependent on various factors such as curriculum, school environment, teacher beliefs and experience. This chapter has managed to critically look at the relevant literature to elucidate these constructs. The following chapter focuses on the research methodology for this study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

In planning for research, it is important to clarify a distinction that needs to be made between methodology and methods, approaches and instruments, styles of research and ways of collecting data (Cohen, Manion & Morrison, 2000). The study sought to explore through a case study, Grade 9 *Natural Science teachers' pedagogical content knowledge of electricity*. The study was guided by the following primary question: How does the teachers' PCK of electricity concepts influence their teaching? The study used qualitative data to answer the following secondary questions: (i) How does the Grade 9 teachers' pedagogical content knowledge manifest during an intervention to strengthen their pedagogic competencies? (ii) How does the selected teachers' orientation to science teaching influence their pedagogical content knowledge? (iii) In what ways do specific characteristics of the professional development programmes contribute to development in the teachers' PCK? In order to address the critical questions, this study makes use of qualitative research methods. This chapter presents the research design, research methodology, research orientation, population, site selection, sampling, data collection procedures, data analysis and ethical considerations.

3.2 Research orientation

An interpretive paradigm was adopted in this study. An interpretive model assumes that researchers have to be immersed in research since all human activity is meaningful and as a result has to be interpreted along with the social context (Sibanda, 2006). The premise of interpretive paradigm is based on the assumption that social reality is not singular or objective, but is rather shaped by human experiences and social contexts (ontology), and is therefore best studied within its socio-historic context by reconciling the subjective interpretations of its various participants (epistemology) (Myers, 2009). According to Cohen *et al* (2000:22), an understanding of the subjective world of human experience is sought by applying what an interpretative paradigm seeks. This is often done by using a variety of techniques to collect data. While approaching this study using interpretive paradigm I was mindful of the fact that my background might have influenced the interpretations of the study since the teachers know me and I was fully engaged in data collection and analysis. However, I acknowledged all the influences on the study and tried to minimise them by using different data collection techniques which are observations, interviews

and workshops. In this study the data collected was analysed and interpreted using the IMTPG model.

3.3 Research design

Mouton (2001:55) asserts that “research design is a plan or blueprint of how the research will be conducted.” Mouton (2001) further explains that research design focuses on the end product, formulates a research problem as a point of departure, and focuses on the logic of research. For this study, a qualitative design was chosen (Miles, Huberman, & Saldana, 2014). Miller and Brewer (2003) attest that qualitative research seeks meaning and contributes to theory development by proceeding inductively. This design incorporates the use of data sources that would allow an in-depth exploration of teachers’ PCK of electricity and how their orientations influenced it. Qualitative approach was chosen because of its strengths which include the following as outlined by Castro, Kellison, Boyd and Kopak (2010:343):

- The capacity for generating richly detailed accounts of human experiences (emotions, beliefs, and behaviours);
- The ability to provide narrative accounts that are examined within the original context in which observations occur; and
- The possibility of supplying an in-depth analysis of complex human and family systems, as well as cultural experiences, in a manner that cannot be fully captured with the use of measurement scales and multivariate models.

To answer the research questions, that is, to capture a variety of pathways, the study involved a limited number of participants with a range of backgrounds, contexts, and teaching experience.

3.4 Research methodology

A case study design was chosen for this research study. Opie (2004) defines a case study as an ‘in-depth study of interactions in a single instance in an enclosed system’. Qualitative case study methodology provides tools for researchers to study complex phenomena within their contexts. A multiple case-study design was chosen because the study entailed one phenomenon in a specific context dealing with different participants (Woodlock, 2010). Each of the participants was treated as a separate case and data from each participant was compared during data analysis. According to Yin (2003), the evidence from multiple cases is often considered more compelling, and the

overall study is therefore regarded as being more robust. The important aim for multiple-case studies is that each case must be selected so that either it predicts similar results (a literal replication) or it produces contrasting results but for predictable reasons (a theoretical replication). Although only four Natural Science teachers from four South African secondary schools in one province (North West Province) and in one district were involved in this study, multiple case study methodology was employed with the hope that it predicted similar results fulfilling a literal replication purpose since all the participants are not producing good results at their schools.

The case study design has some weaknesses. Kerlinger (1986:348) identifies and groups three types of weaknesses of the case study or qualitative research and these are, firstly: the inability to manipulate independent variables; secondly, there is a possibility of misinterpretation; thirdly, randomising is not guaranteed. It has to be pointed out that the purpose of this study from the beginning was neither to manipulate independent variables nor to provide randomisation. The issue of a possibility of misinterpretation was handled through data triangulation techniques and qualitative procedures such as trustworthiness. According to Kerlinger (1986), what the case study can offer is an in-depth understanding of how various aspects in the case interrelate. It is the in-depth understanding of the phenomenon under discussion which this study sought to establish. Case study is thus uniquely placed to deliver explanatory theory. Another disadvantage of a case study is that findings of a single case study may fall short in their representativeness. In this regard there is need to carry out many studies through case studies or other methods to get findings that are a true reflection of the situation in an environment of specific context with regards to the problem being investigated in a study. According to Gerring (2004), findings of a case study may be generalised to a larger class of similar units that have unit homogeneity with the case and therefore are comparable. As mentioned earlier, generalisation was not the purpose of this study. Punch (2009) also concedes that case studies can produce potentially generalisable results through conceptualizing and developing propositions. In this study, the findings can only be generalised to poor performing schools in the Moses Kotane Area Office with the same contextual factors since the Grade 9 Natural Science performance in all the secondary schools in this Area office is very poor. In this study, an attempt was made to assist teachers in enhancing their PCK about electricity through workshops in order to improve on learner performance.

3.5 Site selection and sampling

3.5.1 Site selection

The study was conducted in four (4) secondary schools in the Moses Kotane East Area Office of the Moses Kotane Local Municipality in the Bojanala District, North West Province in the Republic of South Africa. The Moses Kotane Local Municipality is located within the Bojanala District in the North West Province. It is the largest of the five municipalities that make up the district, accounting for a third of its geographical area. It was established after re-demarcation of municipal boundaries and subsequent municipal elections in 2000. The municipality has a predominantly black African population, with fewer Indian, coloured and white groups.

All four teachers are teaching in schools which are in rural villages and previously disadvantaged. Learner enrolment in all the four schools is below 400 and the average number of Grade 9 learners per class is 35. The medium of instruction in these schools is English and home language is Setswana. The school population in all the four schools comprises of only black South African learners. The selected schools do not have the necessary infrastructure for Science teaching like science laboratories and computer laboratories. Learners in these schools do not pay school fees and as a result it is difficult for the schools to buy science laboratory equipment to enhance teaching and learning. Learners' performance in these schools has been unsatisfactory at Grade 9 Natural Sciences for more than 3 years. Figure 3.1 is a map of North West Province indicating where Moses Kotane Municipality is situated.

3.5.2 Sampling and Participants

Purposive sampling was used in this study. It is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources (Patton, 2002). This involves identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Creswell & Plano Clark, 2011). In addition to knowledge and experience, Bernard (2002) notes the importance of availability and willingness to participate, and the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner. This was the criteria employed by this study to select study participants.



Figure 3.1: A map of North West Province indicating where Moses Kotane Municipality is situated

Maree (2015:334) states that purposive sampling means that participants are selected based on some defining characteristics that make them the data needed for the study. The participants were selected from four (4) secondary schools, all with more than two years' experience in teaching. They are all verified by South African Council of Educators (SACE) as being fit to teach in South African classrooms despite their nationality or country of origin. For purposes of maintaining anonymity and confidentiality, the teacher at school A is referred to as Teacher A, the one at school B is referred to as Teacher B, the one at school C is referred to as Teacher C and the one at school D is referred to as Teacher D. A summary of the participants' biographical data is presented in the Table 3.1.

Their respective learners became participants specifically during classroom observations in the study by virtue of being learners in the participant teachers' classrooms. All the participants could easily be accessed.

3.6 Research process

The aim of the study was to explore *Grade 9 Natural Sciences teachers' PCK in the teaching of electricity*. The research was carried out in several stages as described below. Firstly, a vast number of literature was consulted around the topic in order to strengthen the background and the context

of the study by picking the grey areas (gaps). This was followed by data collection through different strategies to respond to the study's research questions.

Table 3.1: A summary of the participants' biographical data

Item	Teacher A	Teacher B	Teacher C	Teacher D
Gender	Male	Female	Male	Male
Nationality	South African	South African	Zimbabwean	Ghanaian
Qualifications	B.Ed	B.Ed (Hons)	B.Sc (Hons) PGCE	B.Sc
Major Subjects	Physics Chemistry Life Sciences	Physics Chemistry Mathematics	Physics Chemistry Mathematics	Physics Electronics Mathematics
Teaching experience	04	16	05	04
Employment status	Permanent	Permanent	Temporary	Temporary

Workshops as a developmental programme were conducted, whereby different topics around electricity were discussed and practical experiments conducted. The next stage was classroom lesson observations where the researcher was a non-participant observer, did not even assist the teachers to develop the lesson plans. Semi- structured interviews were also conducted with individual participants.

3.7 Data gathering techniques

The objective of this study was to obtain detailed information about teachers' PCK in teaching the topic on electricity at Grade 9 level. Professional development workshops, lesson observations and

semi- structured interviews were used as data collection methods in this case study to explore Grade 9 Natural Sciences teachers' PCK of the topic - Electricity.

3.7.1 Professional development workshops

According to Ørngreen and Levinsen (2017), a workshop means an arranged event of a limited duration whereby a group of people learn, acquire new knowledge, perform creative problem-solving, or innovate in relation to a domain-specific issue. It is specifically designed to fulfil a research purpose: to produce reliable and valid data about the domain in question and conducted by people with experience within the domain and they promote genuine participation (Jaipal & Figg, 2010; Yurdakul, et al., 2012; Baran, et al., 2014). The participant group is kept small to allow everyone personal attention and the chance to be heard. The participants are expected to actively participate and influence the workshop's direction, as well as practice the relevant techniques, skills, situations, hence it was chosen as a data collection strategy in this study.

A workshop as a professional learning programme was conducted over a period of four days for two sessions which were aimed to last for 3 hours each, starting at 12h00. These were for both theory and practical tasks on Electricity as a Grade 9 topic. The other two days were for reflection after implementation in the classroom. There was a break between the two sessions for implementation at the schools. They involved the sharing of insights about teaching and learning between teachers in order to gain a sense of professional control. The Subject Advisor responsible for Natural Sciences in the Area Office together with the researcher facilitated the workshops. One could observe an increased level of participation during the second session; it was an interesting interactive session. Participants were also given a chance to evaluate the workshops at the end of the last day. Through the discussions and practical tasks conducted, the teachers' PCK on electricity was explored.

Below is an overview of the workshops that were conducted, aimed at assisting educators to effectively teach the topic on Electricity for grade 9 learners (Table 3.2).

Table 3.2: Workshops Presentation Outline

DAY	ACTIVITY
1	- I welcomed the participants and asked one of them to pray - We all introduced ourselves to make it easy to engage with each other - Explained materials issued to participants - Discussed the workshop objectives - Introduction, teaching and discussion of the following topics: - During the presentation, the participants were allowed to stop me and ask questions, make inputs and comments. Topic 1— Circuits and current electricity Topic 2— Components of a circuit Topic 3— Effects of an electric circuit Break (we took 15 minutes break) Topic 4— Resistance and uses of resistors - Discussions and end of day 1.
DAY 2	- I welcomed the participants and asked one of them to pray - One of the teachers presented a short reflection of day 1 activities - Introduction, teaching and discussion of the following topics: - During the presentation, the participants were allowed to stop me and ask questions, make inputs and comments. Topic 5- Factors that affect resistance in a circuit Topic 6 - Electric cells as energy systems Break (we took 15 minutes break) Topic 7 - Series and parallel circuits Topic 8- Safety with electricity - End of the session
DAY 3	- I welcomed the participants and asked one of them to pray - All of the teachers gave a brief presentation of whether they were able to apply what they learnt during the previous session, give scenario of what happened in their classrooms. - Materials were given out to teachers and we conducted experiments in groups. - Discussions and demonstrations took place concurrently with the experiments. Break - Practical tasks and demonstrations continued - End of the session
DAY 4	- I welcomed the participants and asked one of them to pray - We followed the same procedure as in the previous day. Practical tasks, demonstrations and discussions Break - Introduced the topic on assessment in Natural Science and different teaching strategies. - Each participant gave a short presentation to demonstrate that they indeed learned something during the workshop sessions. - Each participant was given a workshop evaluation sheet to complete - End of the workshop sessions

3.7.2 Classroom observations

Stake (2010) comprehends observations as a means by which the researcher documents what she sees, hears, and feels of an event or activity for the purpose of recording the event or activity in an attempt to make sense of what is happening. The researcher goes to the research site to gather information of what is actually taking place; what Bertram and Christiansen (2014) refer to as first-hand data as opposed to getting information from someone else. Lesson observations were conducted as a data collection strategy. Two lessons observation per teacher were conducted. Observations took place over a period of eight days; two days were allocated for each teacher but they were not consecutive. The observations were conducted after the workshop sessions determine the impact they had on the teachers' PCK in teaching of electricity. The teachers individually developed their own lesson plans according to the Annual Teaching Plan (ATP) provided by the Subject Advisor at the beginning of the year. Fortunately, all the teachers had the ATP so it was easy for them to follow the guidelines and develop their lesson plans.

In this study, the observations had a structured schedule which was pre-arranged with the teachers and the schools. The teachers provided the researcher with their timetables so that observations could be conducted during their normal teaching time. However, I checked them before the lesson observations to ensure that I will be observing the right topic being taught. The principal and the teacher were reminded of the visit a day before the actual visit. I was present in the lessons, but did not participate by, for example, co-teaching or becoming part of the classroom discussions. However, I was available if the teacher wanted to ask questions on the content that was taught or any other issue which came up. I remained seated at the back of the room while the teaching took place, in an attempt to let the interactions in the classroom carry on as if I had not been present. The lesson observations enabled me to get information first-hand as alluded to Bertram and Christiansen (2014). They also afforded me the opportunity to obtain a deeper understanding of information being investigated as I was also in a position to get data that I might not access from teachers if I had only interviewed them. I was able to gather information on the teachers' PCK of electricity during all my lesson observations. The data collected was then later transcribed verbatim and used for data analysis.

3.7.3 Semi-structured Interviews

According to Bryman et al. (2017), an interview is the best primary source of data whereby the researcher can access more in-depth information from each respondent by asking open questions, as well as follow-up questions. Semi-structured interviews are pre-planned conversations guided

by a set of initial questions, but which allow for deviation from the set questions (Opie, 2004). These interviews provide flexible opportunities to probe for greater depth than what recordings can provide. In this study, the semi-structured interviews were used to clarify, supplement and support what was observed in the classroom and provided information that could not be captured by observations alone.

All the four participating natural science educators were interviewed only once during the study. The teachers were individually interviewed on separate days, at their respective schools, behind closed doors to maintain confidentiality. The interviews were conducted immediately after school because I did not want to disturb the teachers as they are expected to teach. The purpose of the educator's interview was to explore the educator's PCK of electricity and determine if they had received any professional training on the topic. The interviews also sought to find out the teachers orientation to science teaching as well as different strategies that teachers use to teach and assist learners to understand the topic of electricity. There was a set of twelve questions to be responded to and it took all the participants about 25-40 minutes to finish with the interview. From their facial expressions I could tell if the teacher understood the question, or whether he was comfortable with the question. This shows that it was important for me to employ the semi- structured interviews as a data collection strategy.

The following are some of the questions that were asked:

1. What do you normally take into consideration in planning a lesson on the topic – Electricity?
2. How often have you attended any professional development intervention on this topic (if any)? *Probing question:* What effect did the training have on your conceptual knowledge (if any)?
3. Which five electricity concepts in your experience, do you consider difficult to teach effectively?

3.8 Data analysis

Data was obtained from professional development workshops, classroom observations and semi-structured interviews. The three data collection methods used in this study produced verbal data (qualitative text) only, there was no numerical data collected. Thus, data analysis followed

interpretivism principles. The Interconnected Model of Teacher Professional Growth (IMTPG) model was used as an analytical tool. Sub-sections 3.8.1 to 3.8.3 below describes how data set from each data collection instrument was processed. Sub-section 3.8.4 describes how data from the three instruments was analysed using the IMTPG as an analytical tool.

3.8.1 Workshops

The workshops' video recordings for every session wherein all of the four teachers were participants were transcribed verbatim. Data collected was re-examined for evidence of the teachers' knowledge and change process. I also applied peer debriefing technique to make aspects of my inquiry more explicit. My peer debriefer was my colleague who is a science subject advisor, qualified and experienced in the field of science. The peer debriefer assisted me a lot in identifying my biases, clarifying my interpretations, and more deeply exploring meanings.

3.8.2 Classroom observations

The classroom observation video recordings for each of the four teachers were transcribed verbatim. Relevant points were noted in the field notes and the recordings of those sections of the class were transcribed and indexed into the field notes, producing a set of integrated observation notes. I also applied peer debriefing technique to make aspects of my inquiry more explicit. The peer debriefer assisted me a lot in identifying my biases, clarifying my interpretations, and more deeply exploring meanings.

3.8.3 Semi-structured Interviews

The audio recordings of the interviews for each of the four teachers were first transcribed verbatim. To ensure accuracy the transcribed interviews were rechecked against the original audio files. Member checking was used throughout the research process to ensure the accuracy of my interpreted summary. The teachers were provided an opportunity to give feedback on the accuracy of the interpretation.

3.8.4 The use of the IMTPG in analysing the data

After all the data was transcribed, it were examined and selected for indications of teacher change using the IMTPG model. According to Stoll (2016), the IMTPG model is based on four analytical domains which holds that:

Change occurs through the mediating processes of ‘reflection’ and ‘enactment’, in four distinct domains which encompass the teacher’s world: the personal domain (teacher knowledge, beliefs and attitudes), the domain of practice (professional experimentation), the domain of consequence (salient outcomes), and the external domain (sources of information, stimulus or support).

Clarke and Hollingsworth’s (2002) IMTPG model uses four domains as the indicators of key elements of change. The External Domain (ED) contained the professional development. Teachers’ conceptions comprised part of the personal domain (PD) along with the teachers’ knowledge and attitude. The domain of practice (DP) encompassed the teachers’ practice and lastly, the domain of consequence (DC) involved the students’ learning. Clarke and Hollingsworth’s (2002) IMTPG model was adopted as the analytical tool as shown in Figure 3.2.

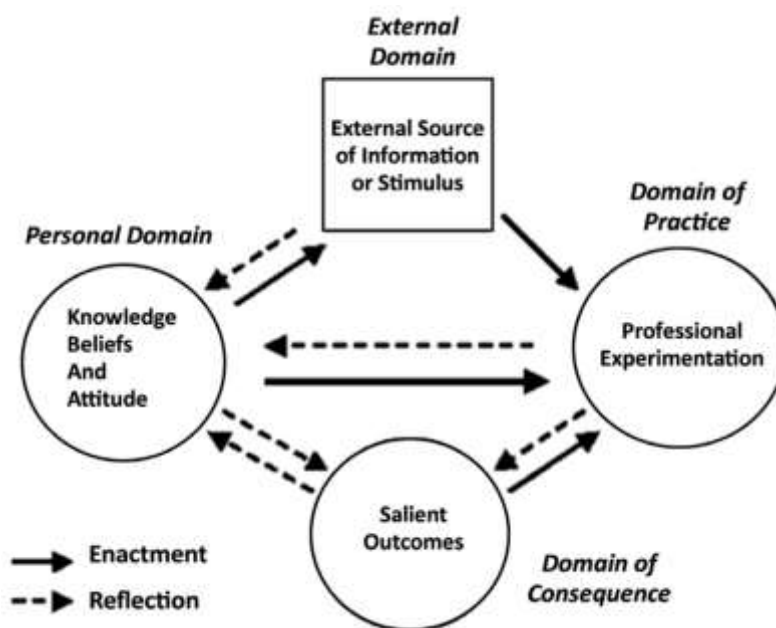


Figure 3.2: Clarke and Hollingsworth’s (2002) IMTPG model

Change can occur in any of the four domains since they are interrelated and show a cyclical nature of change but will distinctly reflect the domain where it occurs. Through the mediating processes of reflection and enactment, change translating from one domain to another occurred. The selected statements indicating change to one of the PCK components suggested by Magnusson et al. (1999)

were categorised. Next, to determine if there were any relations between domains of the IMTPG, the changes were examined using the adapted criteria from Justi and Van Driel (2006) as shown on Table 3.3. Since change can occur in any of the four domains, it was important to determine in which domain the entry point occurred, and how this affected the other domains.

According to Clarke and Hollingsworth (2002: 958), the process by which changes occur can be represented as a change sequence which consists of two or more domains together with the reflective or enactive links connecting these domains. The changes can also be presented as a growth network, when change sequences go further, thus demonstrating “the occurrence of change that is more than momentary” (Clarke & Hollingsworth, 2002:958). It is important to note the distinction between a change sequence and a growth network since it helps to identify straightforward and superficial changes in teachers’ knowledge, from more complex and lasting changes. Pictorial representation (pictogram) for the development of each PCK component, showing relationships between the domains of the IMTPG were constructed. Finally, for each teacher, the relationships established between the four domains in relation to each of the nine aspects were represented in a summarised picture of the IMTPG. This resulted in 36 (four times nine) pictorial representations of the IMTPG.

Table 3.3: Criteria used in this study to establish relations in the IMTPG (adapted from Justi and Van Driel (2006))

Relationship	Mediation	Criteria for establishment
1. From PD to ED	Enactment	When a specific aspect of teachers' initial content knowledge, curricular knowledge, or PCK on electricity influenced what they did or said during one of the learning activities in which they took part.
2. From ED to PD	Reflection	When something that happened during the learning activities modified the teacher's initial content knowledge, curricular knowledge, or PCK on electricity
3. From ED to DP	Enactment	When something that happened during the learning activities influenced something that occurred in teaching practice
4. From PD to DP	Enactment	When a specific aspect of the teacher's orientations or beliefs (initial content knowledge, curricular knowledge, or PCK on electricity) influenced something that occurred in teaching practice
5. From DP to PD	Reflection	When something that teachers did in their teaching practice modified their content knowledge, curricular knowledge, or PCK on electricity (cognitions or beliefs)
6. From DP to DC	Reflection	When something that teachers or their students did in their teaching practice caused specific outcomes(such as student learning, teacher control, student motivation, and student development)
7. From DC to DP	Enactment	When a specific outcome made the teachers change their practice at that moment and they state how they would modify the associated teaching practice in the future
8. From DC to PD	Reflection	When teachers reflected on a specific outcome, thus changing a specific aspect of their previous content knowledge, curricular knowledge, or PCK on electricity
9. From PD to DC	Reflection	When a specific aspect of the teacher's cognition helped them in reflecting on/analysing a specific outcome of their teaching practice

PD = personal domain; ED = external domain; DP = domain of practice; DC =domain of consequence

3.9 Data management

Mika (2018) asserts that effective processes of consistency, collecting, recording and storing data securely are an indication of good data management. Due to the amount of data that was collected using different instruments, I focused on data that were relevant and important to the study. As I sorted the data, I kept copies of documents (both hard and soft copies) and saved. I created a research data file which was safely kept at home wherein I kept all the hard copies. I also created a folder on my desktop where I kept soft copies of each item as a back-up. The folder was password-locked to ensure confidentiality of the data contained therein. According to North West University, Faculty of Education's Research Ethics Committee, this data shall be stored as such for up to 7 years and then destroyed thereafter.

3.10 Trustworthiness

The main purpose of the case study design is to understand the different truths about a phenomenon or a similar one (Creswell, 2009), hence qualitative researchers are more concerned about the trustworthiness of the findings. According to Schwandt, et al. (2007), trustworthiness is the measure of trust that the researcher has in the qualitative data since it is credible, transferable and dependable. To ensure the trustworthiness of the research in relation to ethical rules and measures, the principles of credibility, dependability, conformability and transferability were observed.

3.10.1 Credibility

Credibility is defined as the extent to which the data and data analysis are believable and true (Holloway & Wheeler, 2002; Macnee & McCabe, 2008). Credibility establishes whether or not the research findings represent the original information drawn from the participants' original data and the data is correctly interpreted. To ensure credibility in this study; I sought support from other professionals willing to provide scholarly guidance, presented my study findings to peers to receive their comments so that I could receive feedback and improve on my findings. I observed the participant's conduct during the lessons and workshops. I also sent data back to the participants for them to evaluate the interpretation made and to suggest changes if they were unhappy with it or if they had been misreported. The member checks strategy was done to ensure that there is no internal conflict or inconsistencies and establishing referential adequacy. With only four

participants, this process was easily executed regardless of the huge amount of data collected with each individual participant.

3.10.2 Transferability

Transferability refers to the degree to which the results of qualitative research are transferable or generalisable into new contexts outside the actual study context (Bitsch, 2005; Tobin & Begley, 2004). It is therefore imperative that the researcher documents and justifies the methodological approach, and describes, in detail, the critical processes and procedures that have helped to construct, shape and connect meanings associated with those phenomena. Throughout the process of this study, I was sensitive to possible biases by being conscious of the possibilities for multiple interpretations of reality. In this study, the aspect of transferability was taken considered by providing a rich, thick description of the study elucidating all the research processes, methodology, data collection strategies, sampling, data analysis and findings. I believe that data and description I provided enabled readers to appraise the significance of the meanings attached to the findings and make their own judgment regarding the transferability of the research outcomes.

3.10.3 Dependability

Gasson (2004) contend that dependability of a research is that the research conducted ought to be ordered across time, researchers, and analysis procedures. To increase the trustworthiness of my study and make it dependable, certain measures were considered. I established an audit trail. I kept all documents for cross-checking the inquiry process: raw data, observation, interview and workshop notes. The code-recode strategy was also applied by coding the same data twice, giving two weeks' gestation period between each coding. This was to compare to see if the results are the same or different. I discussed my research process and findings with a colleague who has experience of qualitative research. The peer examination was done so that I was helped identify the categories not covered by the research questions or help to identify negative cases. I used purposive sampling with some element of convenience as a criterion to select the four Grade 9 Natural Science teachers and their contexts. The teachers provided the researcher with their timetables so that observations could be conducted during their normal teaching time. During observations, I tried as much as possible to collect data with the minimum influence on the classroom setting. Interviews were done after the school teaching hours so that the teachers' working hours were not compromised. During the workshops I explained the objectives and the

material used to ensure that they are able to participate. Discussions were allowed during the presentations so that no participant is left behind and they fully understood what was being done. Lastly, this study involved humans and so ethical clearance was mandatory and it was sought as detailed in section on ethical clearance.

3.10.4 Conformability

According to Pandey and Patnaik (2014:5746), in qualitative research “Conformability can be seen as a degree of neutrality or the extent to which the findings of a study are shaped by the respondents and not researcher bias, motivation or interest”. It is the degree to which the results of an inquiry could be confirmed or corroborated by other researchers. According to Gasson (2004), this means the researcher must ensure as much as possible that the findings are the consequence of the experiences of the informants rather than the inclinations and convictions of the researcher. In order to confirm conformability, I kept a reflexive journal which included all events that happened in the field and personal reflections in relation to the study. Both the lesson observations and workshops were video- recorded and individual interviews’ responses were recorded. Whenever clarification was needed after a data collection phase, I consulted individual teachers through telephone calls.

3.11 Ethical considerations

Ethical guidelines for the research study included, but were not limited to, informed consent, confidentiality, anonymity and privacy (McMillan & Schumacher, 2001). Firstly, I applied for ethical clearance from the North West University’s Research Ethics committee and it was granted (see Appendix A). Permission to conduct the study was sought from the North West Department of Education under whose jurisdiction the schools fall since they are public schools. A letter of approval (see Appendix C) was issued after submission of the application letter (Appendix B) to North West Department of Education Head Offices in Mafikeng. After approval of my ethics application by the North West Department of Education Head Office, I then requested permission from the Moses Kotane East Area Office Manager (see Appendix D) to access the sampled schools to conduct my research study. Although four separate schools were involved in this study, the procedure followed to access these schools was exactly the same.

I went in person to the four schools to request permission from the principals of these schools. I handed the request letter (see Appendix D) to each of the four principals. This was then followed

with a brief description of the intended study. Transparency was ensured by openly discussing the purpose, the objectives, and the goals of the research, the research questions the study sought to answer with everyone who will be involved in the research. At no time did I withhold information about the true nature of the research. All the four principals verbally accepted my request to conduct the study at their respective schools before signing, and both showed a lot of enthusiasm in my intended study and were hopeful that the study will impact positively on the teaching and learning of Physical Sciences in their schools. They expressed their concern with the general performance in Natural Sciences. After meeting the principals, I then met with the respective Head of Science Department (HoD) of each school who I then briefed about my study. However, two of the schools did not have a HoD. This was then followed by a meeting with the Grade 9 Natural Sciences teachers at each school. All the four schools have only one Natural Sciences teacher. After the introductions and briefing on the study discussing the purpose, the objectives, and the goals of the research, the research questions the study sought to answer, they all agreed to be participants in the study.

I then gave each of them the information sheet (see Appendix E) requesting their voluntary participation in the study by allowing me to observe and video record, at least, two lessons per participant teacher. The four teachers were then requested to sign the teacher's consent form giving their permission to lesson observations and also to video recording during the lesson observations (see Appendix F).

Although the participant teachers' respective learners were not directly involved in the study still, they are considered participants when data collection is done through direct observation of classroom lessons. Therefore, I had to meet up with the participant teachers' respective learners. I then briefed the learners about my study and all learners agreed to participate in the study. Consent was also sought from learners' parents who were below the age of 18 and this turned out to be parents of all learners whose classes were part of the study (see Appendix G). A timetable was set up for when I could visit the four schools to observe natural science lessons and also to do interviews with the participant teachers.

The rights of respondents were protected, and they were not forced to participate in the study or respond to questions during interviews. Participants were informed that they could withdraw at any time of the study if they so wished. I respected and safeguarded the safety, dignity and self-

worth of all the research participants by being mindful of the cultural, religious, gender and other significant differences. The questions and statements were framed objectively to widen the social scope of the study and sensitivity to cultural and social differences was adhered to. That is, the questions and statements were structured and prepared in such a way that they could give a true reflection of the teachers' PCK of Electricity as a topic at Grade 9.

3.12 Summary

In this chapter, a discussion of the overall approach (the qualitative case study approach), used in this study was presented. The choice of methodology and the research methods used in the study were also discussed. Classroom observations, interviews and workshops were used as the data collection methods and provided invaluable information for the study. Sampling of participant teachers (purposive sampling), sample size, data analysis, data management and ethical procedures were also discussed. In the next chapter, focus is on data presentation and discussion.

CHAPTER 4: PRESENTATION OF RESULTS, INTERPRETATION AND DISCUSSION

4.1 Introduction

This chapter presents results, researcher's interpretation of the results obtained and discussion. In this study, data was obtained from professional development workshops, classroom observations and semi-structured interviews. The three data collection methods used in this study produced verbal data (qualitative text) only, and there was no numerical data collected. After all the data was transcribed, it were examined and selected for indications of teacher change using the Interconnected Model of Teacher Professional Growth (IMTPG) model. I used this IMTPG in this study because it offers the opportunity to study different patterns of change leading to teachers' growth (Clarke & Hollingsworth, 2002).

4.2 The use of the IMTPG in analysing the data

In order to study how a change in one domain triggers a change in another domain, I used, as customary in this model, the mediating processes of 'enactment' and 'reflection' as defined by Clarke and Hollingsworth (2002). These pathways can result in either a 'change sequence' (CS) or a 'growth network' (GN). When a change in one domain, often supported by enactive or reflective links leads to a change in another then we have 'Change sequences' which are superficial changes. A more complex and ongoing change in more than one domain results in a 'growth network' and it is a more lasting change. Through the mediating processes of reflection and enactment, change translating from one domain to another occurred. A solid arrow was used to show enactment and a broken arrow was used to show a reflection of a change in domains. The enactment and reflection are the mediating processes that triggered the change effect (Justi & Driel, 2006). An adaptation by using two arrows (equally numbered) was used to indicate parallel mediating processes when one domain triggered changes in two different domains. For example, I found situations in which the professional development programme (located in the External Domain) led to changes in his knowledge of circuit connections (Personal Domain) and at the same time caused the teacher to change ways of conducting of experiments (Domain of Practice) in the classroom.

The selected statements indicating change to one of the PCK components suggested by Magnusson et al. (1999) were categorised. Those five components are: (1) orientations towards teaching science; (2) knowledge of science curricula; (3) knowledge of instructional strategies; (4)

knowledge of student understanding of science; and (5) knowledge of student assessment. Data was analysed for each participant to be able to respond to the main research question. Next, to determine if there were any relations between domains of the IMTPG, the changes were examined using the adapted criteria from Justi and Van Driel (2006) (Table3.2). Since change can occur in any of the four domains, it was important to determine in which domain the entry point occurred, and how this affected the other domains.

In the following sections codes are used to indicate the different domains of IMTPG affected in components of PCK by Magnusson et al. (1999):

PD = personal domain; ED = external domain; DP = domain of practice; DC =domain of consequence; CS = change sequence; GN = growth network; T1= Teacher 1; T2= Teacher 2; T3= Teacher 3 and T4= Teacher 4.

4.3 Presentation of data and interpretation

4.3.1 Orientations towards teaching science

Orientations towards teaching science refers to their beliefs and goals of teaching science as well as teaching methods and context dependent information on content. Data on teachers' orientations towards science teaching is shown in figure 4.1.

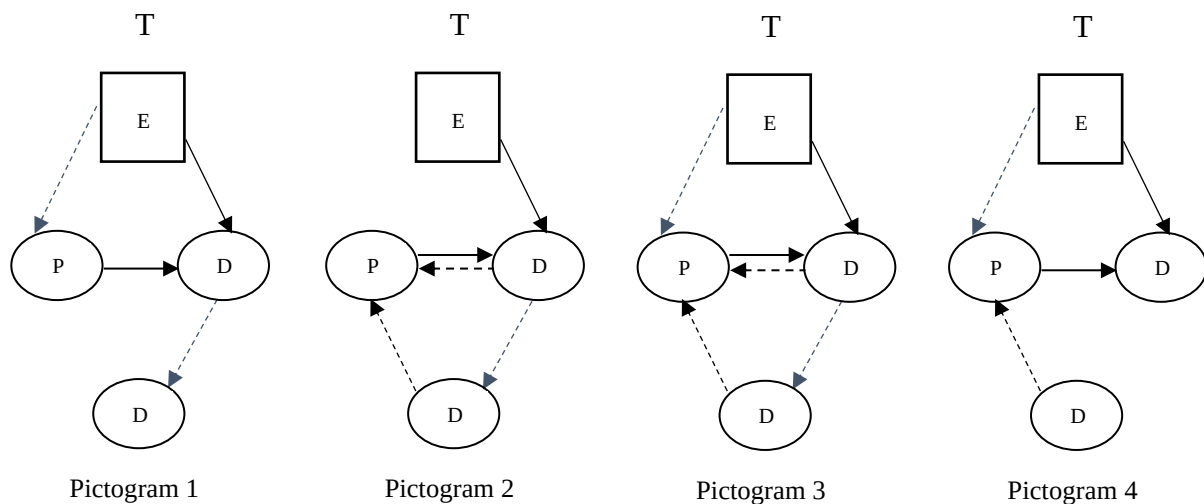


Figure 4.1: The development of teachers' orientation towards science teaching

Teacher 1

In the extended model of figure 4.1, pictogram 1, it is clear that there was a change sequence with an enactment of the ED on the DP and also the ED stimulated a reflection on the teacher's beliefs, ED→PD. This resulted in his enactment of personal knowledge and beliefs on the DP (PD→DP). T1 had doubts about what and how to teach during the first lesson observation, he was not very confident about his goals to teaching science and particularly electricity. However, class experiences were positive during the second observation which were after the practical workshops and these had an influence on his beliefs and goals to teaching science DP→DC.

Extract 4.1

First lesson observation

T1: What do you understand by electric current?

L4 (Learner 4): Electric current is the electricity wires in our homes and in the school, let me say everywhere.

L9 (Learner 9): It is electricity (giggles)

L12 (Learner 12): Teacher X once said it is the flow of charges

L16 (Learner 16): No, Teacher X said it is the flow of electrons, hence we say electricity.

T1: You are all not far from the correct answer. Electric currents are the flow of any electric charge meaning both protons and electrons. It all depends on what you use. (Writes it on the board).

Second lesson observation

T1: Today we are going to do experiments neh, you always struggle with how resistance affects the brightness of the bulbs and how current is split in a circuit so today we are focusing on that. (Splits learners into 8 groups of 6 each and asks each group to come collect the material they need for the practicals that he had already packed for them). The learners move around to sit as instructed by the teacher.

T1: I want you to arrange a circuit with 2 cells and 2 bulbs in series with resistor in between the cells; then rearrange the circuit, this time connect the bulbs in parallel but in series with the resistor, thirdly connect the 2 cells and the 2 bulbs in series but do not connect the resistor. Note the brightness of the cells in both instances and come up with possible explanations for your observations.

He moves around the groups, observing them and interacting with them. After 20 minutes, he stops them and then explains the reasons why the bulbs were brighter in some instances.

Teacher 2

Figure 4.1 shows that T2 exhibit meaningful patterns of information on his goals for science teaching; core conceptions that guide his thinking on the electricity concept; and displayed varying amount of adaptability in the application of his knowledge. A growth network can be seen in pictogram 2 and involved the PD enactment on DP; the ED enactment on the DP; stimulating a reflection of the DP on the PD. After the second workshop the changes were a visible reflection of DP→DC; and DC →PD.

Teacher 3

In figure 4.1, pictogram 3 depicts a growth network and there was a noticeable change in his teaching of electricity; PD to DP and a reflection on his teaching DP→DC. Through the collaboration, reflections between the workshop facilitator and the teacher enabled T3 to begin constructing new beliefs (ED→PD), influenced by learning how to listen to his science students resulting in a reflection from DC to PD. These new beliefs resulted in a shift in the classroom from exclusively teacher-centred to more student-centred approach in teaching electricity, stimulating a reflection of DP to PD.

Extract 4.2

T3 walks into a class, greets the learners and starts writing on the chalkboard. Thereafter he asks the learners questions based on what he has written. None of the learners respond for about 2 minutes then some learners begin to raise their hands.

L2 (Learner 2): Sorry sir, you promised us to do the experiments today, are we still going to do them?

L7 (Learner 7): Sir I think we should start with the experiments before the questions, this is difficult for us. (The class becomes noisy as the learners unanimously agree to start with the experiments).

T3: Ok we'll do the experiments if that will make you understand but that's not what I wanted.

L22 (Learner 22): But sir you saw yesterday that we struggled, I personally did not understand anything. Please let's do the experiments.

T3 instructs them to sit in their groups and hands out the materials for conducting the experiments. He then gives out an information sheet to each group and allows them to continue with the experiments.

Teacher 4

Although T4 was appropriately qualified to teach science, he indicated that he did not learn physics through the same methods that he should use when teaching. A change sequence is observed whereby his PD influenced his DP; and also his knowledge from university and the internet that he always consults ED influenced his DP as well as his PD but there was no reflection from his DP. However, it is worth noting that during the interview he indicated that his beliefs on the goals for teaching science were positively changed through interactions with other teachers (DC→PD).

Extract 4.3

Researcher: Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge?

T4 (Teacher 4): Yes I attended content training workshop on the topic. I learned a lot, how to approach different concepts especially division of current and resistance which I struggled with but was not satisfied because the time allocated was very little.

Researcher: Did you achieve some of your professional development needs because of the workshops I conducted on this topic? Did you gain anything?

T 4 (Teacher 4): Shuu, I have never attended workshops so informative and developmental like these before, thank you very much. The other teachers were amazing, I didn't think I will enjoy teaching and be able to simply electricity to my learners until now. I learned different strategies to teach the topic, assess the learners and which instrument to use. Atleast I have confidence to perform demonstrations, practical experiments and assess them. I promise you I will apply all the methods I learned in my science teaching, no more homeworks and tests only.

4.3.2 Knowledge of the science curriculum

Knowledge of the science curriculum refers to teachers' knowledge of the goals and objectives for students in the subject(s) they are teaching, knowledge about the elements of the science curriculum; variety of instructional tools presented in the science curriculum and how to use them and knowledge about the topic at hand. This category of the PCK component has been divided into two.

4.3.2.1 Knowledge of specific curricular content

Knowledge of specific curricular content refers to knowledge of subject content, different materials, activities, resources and programs that are relevant to teaching a particular domain of science and specific topics within that domain. Figure 4.2 below indicates the results for all the teachers on this aspect.

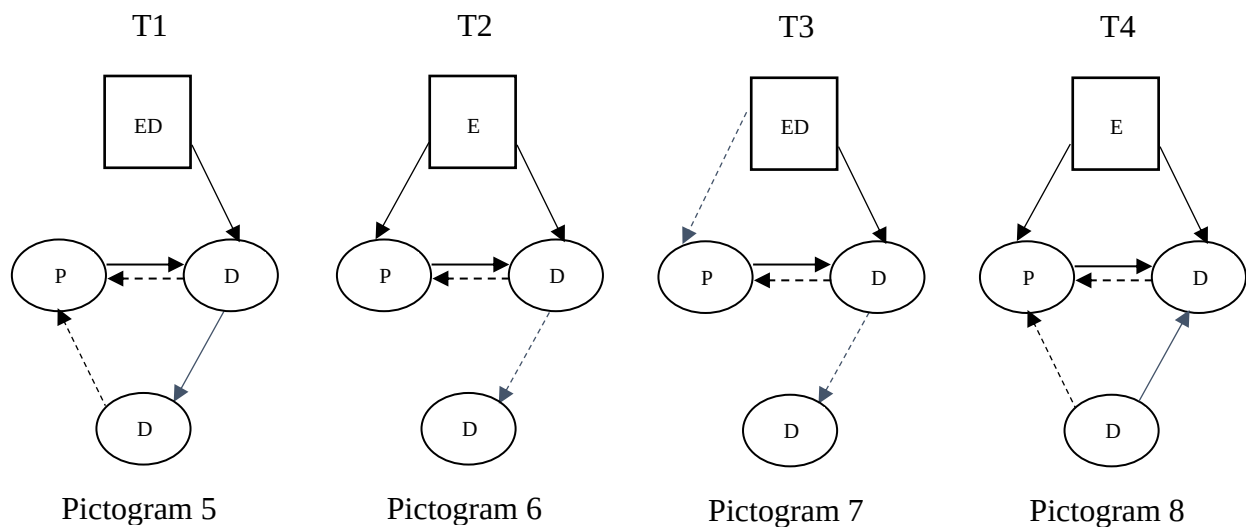


Figure 4.2: The development of teachers' knowledge of specific curricular content

Teacher 1

A central growth network pattern was observed in pictogram 5 and it involved (1) the PD enactment on the DP; (2) as well as the enactment of ED on DP; stimulating a reflection of the DP on the PD; (3) leading to an enactment of the changed DP on the DC. Breaking this down, the teacher at first seemed to lack underlying knowledge of science curriculum and limited applicability and his teaching was teacher oriented. After the workshops, an observation was made on how easily he implemented a variety of instructional strategies. His confidence was boosted (DC→PD) and students actively participated in their learning, were able to conduct experiments and respond to his questions. He indicated that his knowledge prior to the workshops was “not enough” to enable him to teach with confidence.

Extract 4.4

Researcher: Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge?

T1 (Teacher 1): I attended content training workshop on the topic at the beginning of the term. It was developmental unfortunately we did not cover everything because there was no electricity, it was very cold and we had to leave earlier because the venue was not conducive. I was not happy but there was nothing I could do.

Researcher: Did you achieve some of your professional development needs because of the workshops I conducted on this topic? Did you gain anything?

T 1 (Teacher 1): These were the most developmental workshops that I have ever attended. I can't said I gained anything but rather say I learned the topic from scratch. My content knowledge before the workshops was not enough, I struggled to confidently prepare for the lesson but now it is a different ball game I can now proudly stand in front of my learners and teach the topic of electricity. I am grateful that I had the opportunity to meet with experienced teachers who were willing to take me by hand to ensure that my knowledge is improved. As a novice teacher I learned different strategies to teach the topic but most importantly I will now be able to apply different assessment methods in my class. I promise you my results will improve going forward.

R: Do you find it easy or difficult to explain the electricity concept to your learners?

T1: I struggled to bring my knowledge down to their level and transfer knowledge to them hence I looked like I do not have content matter. But I am confident that I will improve a lot after the workshops.

Teacher 2

In pictogram 6 a growth network is observed with T2 which involved: the ED enactment on the DP; the PD enactment on the DP; the ED enactment on the PD; stimulating a reflection of the DP on the PD as well as the DP on the DC. T2 displayed high knowledge of the science curriculum and more developed content knowledge of electricity. He asked learners relevant questions, conducted demonstrations and explained the different concepts with ease. He shared with the other teachers which materials he uses from home to conduct experiments, which internet sites he visits for more knowledge. He attributed his knowledge to always consulting the internet, attending teacher forums and engaging in collaborative planning with teachers (ED→PD) on top of his qualifications. All these made it possible for him to adapt teaching resources to suit his students' diverse needs and level of learning.

Teacher 3

Whilst endeavouring to enhance his subject knowledge and adapt it to the students' level, T3 realised that he also had to consider pedagogical perspectives. A central growth network pattern was observed in pictogram 7 and it involved: the ED enactment on the DP; the PD enactment on the DP; stimulating a reflection of the DP on the PD as well as the DP on the DC. He indicated that interaction with science teachers during the workshop helped him become more innovative to conduct experiments and also enhanced his content knowledge of electricity (ED→PD).

Extract 4.5

R: Do you find it easy or difficult to explain the electricity concept to your learners?

T3: Although I know this subject like I know my name, I struggle to convey the information to the students in an appealing and comprehensive manner that instils enjoyment in their learning, I am frustrated.

Researcher: Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge?

T3: Yes, every year we attend workshops on this topic at the beginning of term 3 but the time is never enough. It is only for 5 hours and that includes administrative work and moderation of teacher files for school-based assessment activities. I cannot out rightly say that I have gained anything from the workshop.

R: Did you achieve some of your professional development needs because of the workshops I conducted on this topic? Did you gain anything?

T3: It is for the first time that I attended a workshop which focused on one thing, content discussed and practical experiments conducted. I met the most helpful and knowledgeable facilitator and teachers who helped me improve on my content knowledge and instructional strategies. I now know that I should improvise and not only rely on demonstrations in my classes. So yaa, I gained a lot.

Teacher 4

Figure 4.2 depicts meaningful patterns of information on his knowledge of science curriculum and knowledge about the topic at hand from his experience and qualifications (ED→PD). A change sequence can be seen in pictograms 8 and involved the PD enactment on DP; the ED enactment on the DP (knowledge from university and workshop). He was able to teach the topic as planned

(PD→DP) but learners seemed not to follow him especially during practical experiments. A reflection could be identified when he indicated that he realised teaching electricity as a topic at grade 9 encompassed much more than having a sound knowledge and subject base (DP→PD). He said *“these students are not pulling their weight in class, they do not write homework and I am discouraged”*. However, he indicated that the workshops have armed him with more strategies to teach the topic and he hopes for better results.

Extract 4.6:

(After giving the learners materials to conduct practical experiments, sits down and instructs them to follow what is written on the information sheet. However, half of the class starts chatting to each other and not conducting the experiment.)

T4: Why are you not doing anything, you are only left with 10 minutes to finish?

L5: Sir, we don't understand what exactly we should do. These things are different from what is drawn on the sheet.

L20: Sir the information sheet has too much information, it is confusing us, please explain again.

T4: What is it exactly that you want me to explain? We discussed about the current, ammeter, voltage, voltmeter, potential difference, resistance so I also can't understand your problems. You are just being lazy and will give you zero if you don't finish on time.

Researcher: Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge?

T4 (Teacher 4): Yes I attended content training workshop on the topic. I learned a lot, how to approach different concepts especially division of current and resistance which I struggled with but was not satisfied because the time allocated was very little.

Researcher: Did you achieve some of your professional development needs because of the workshops I conducted on this topic? Did you gain anything?

T 4 (Teacher 4): Shuu, I have never attended workshops so informative and developmental like these before, thank you very much. The other teachers were amazing, I didn't think I will enjoy teaching and be able to simply electricity to my learners until now. I learned different strategies to teach the topic, assess the learners and which instrument to use. Atleast I have confidence to perform demonstrations, practical experiments and assess them. I promise you I will apply all the methods I learned in my science teaching, no more homeworks and tests only.

4.3.2.2 Knowledge about topic specific terminology

This component of pedagogical content knowledge refers to the knowledge teachers must have on different terminology in the topic, what it means and how is it related to each other. Results are shown in figure 4.3 below.

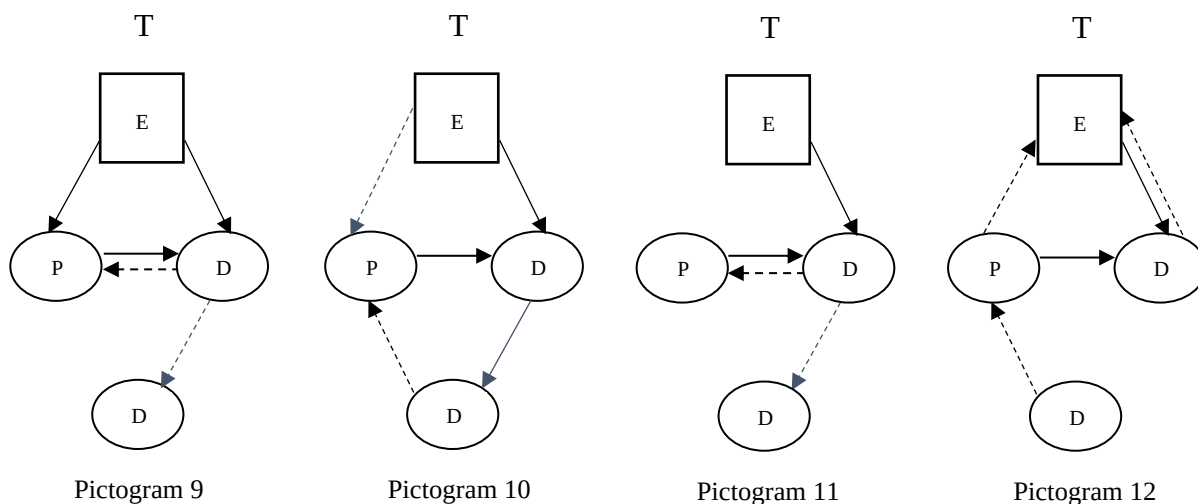


Figure 4.3: The development of teachers' knowledge about different terminology in teaching of electricity

Teacher 1

Figure 4.5 shows growth network for T1 in pictogram 9 which involved: an enactment of the ED (knowledge from university) on his PD as well as his DP (class teaching). The students' active participation was a reflection of the knowledge he gained through the workshops, DP→DC.

Extract 4.7

T1: What do you understand by electric current?

L12 (Learner 12): Teacher X once said it is the flow of charges

L16 (Learner 16): No, Teacher X said it is the flow of electrons, hence we say electricity.

T1: You are all not far from the correct answer. Electric currents are the flow of any electric charge meaning both protons and electrons. It all depends on what you use.

T1: What is potential difference?

L19: Potential difference is the energy that is needed in the circuit to have the lights on.

T1: Why do you say that, do you mean that without potential difference the bulbs will not light?

L19: Yes sir

L 24: It is the energy supplied by the cells to the circuit.

T1: Ok class, Potential difference is the amount of energy supplied to the components on a specific circuit, not necessarily the whole circuit itself.

Teacher 2

A change sequence is observed for T2 since he had both pedagogical and subject content knowledge of the topic electricity. In pictogram 10, an enactment of his ED and PD on the DP resulted in a reflection on his PD.

Extract 4.8:

R: Do you find it easy or difficult to explain the electricity concept to your learners?

T2: Not really, it's just that I learn something new from them daily. They make me to come well prepared to the class.

Teacher 3

In pictogram 11 a growth network was observed for T3 and involved: an enactment of his ED and PD on his knowledge and usage of the different terminologies in teaching of electricity (DP). The manner in which he explained the concepts and taught learners to calculate resistance, current and voltage seemed to be easy to follow (DC).

Teacher 4

In figure 4.5 pictogram 12 it is shown that the teacher's knowledge from university, internet, workshops (ED) as well as his personal knowledge (PD) had an enactment on his DP. He displayed a high knowledge of electricity terminology, but the students struggled to understand him. There was a growth network pattern observed, even though there was no reflection on the DC by the DP since the learning outcomes were unsatisfactory.

4.3.3 Knowledge of instructional strategies

Knowledge of instructional strategies covers knowledge of both subject-specific and topic specific teaching strategies. Strategies in these categories differ with respect to their scope. The teacher

should be able to use appropriate activities in instruction, use real life examples and analogies in instruction and make use of different representations in instruction.

This category of the PCK component has been divided into two.

4.3.3.1 Knowledge of Subject-specific strategies

Knowledge of subject-specific strategies refers to general approaches to or overall schemes for enacting science instruction. The strategies are specific to teaching science only, broadly applicable and consists of the ability to describe and demonstrate a strategy and its phases. The development of the teachers' knowledge of subject-specific strategies is shown in figure 4.4 below.

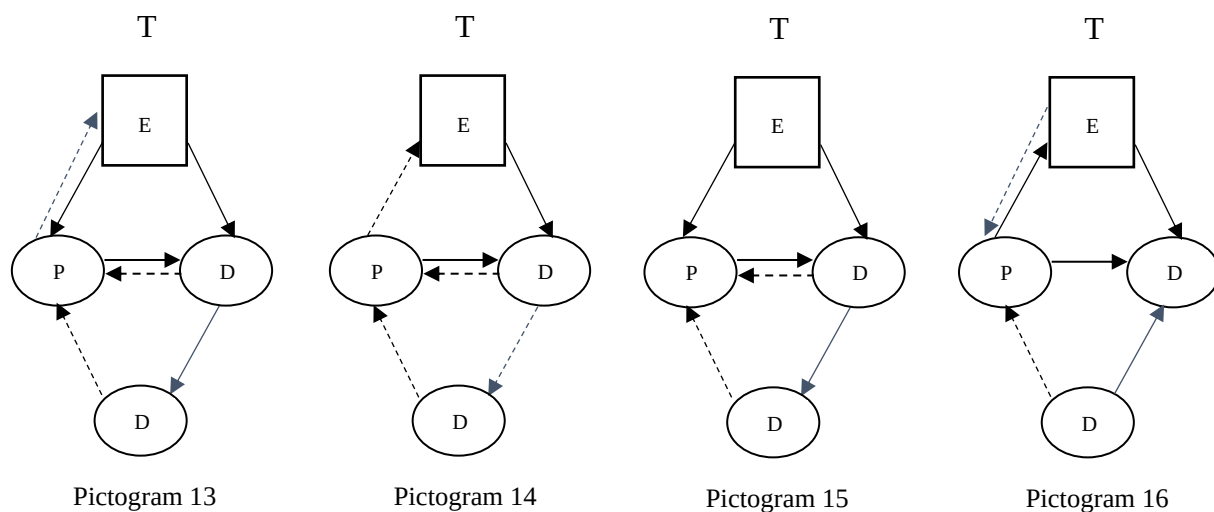


Figure 4.4: The development of teachers' knowledge of subject-specific strategies

Teacher 1

In Figure 4.3 a central growth network pattern can be observed in pictogram 13 and it involved the ED enactment on the PD through his prior knowledge from university; as well as the enactment of ED on DP visible in him adapting the lesson plan from the textbook to his class; leading to an enactment of the changed PD on the DP and stimulating a reflection of the DP on the PD. T1 used a variety of instructional strategies in teaching electricity. He asked questions, allowed the students to work in groups and did some demonstrations during the lessons. This was a reflection of DC on his PD.

Teacher 2

Pictogram 14 depicts a growth network in which the teacher's ED influenced his DP. Through his experience of teaching science, his PD enacted on his DP and resulted in a reflection of the DP on his PD. He began his instruction on electricity by asking an open-ended question on the students' knowledge of electricity. He then wrote down key phrases from the students' responses and did not immediately correct an obvious wrong answer. He was able to design teaching material different from the ones provided that enhanced his instructional strategies, indicating a reflection of his PD on the ED. T2 commented on his instructional strategies and reflected on the experience, indicating that he considered students' outcomes as important in his teaching DC→PD.

Teacher 3

A growth network was observed as the teacher illustrated specialised knowledge of different instructional strategies in teaching science. His knowledge of electricity from the university and the internet had an enactment on his PD. That resulted in him being able to apply the strategies like asking the students questions and not directly answering the student's questions with ease. In pictogram 15 it can be observed that the reflection on the PD by the DP is clearly displayed when the students' answers suggested a discomfort with the ambiguity, implying this was an unfamiliar place for him.

Teacher 4

The teacher's knowledge of electricity had a direct enactment on his ED (he changed the manuals for tutorials) and his classroom practices. Pictogram 16 illustrated a growth network with the following observations: the teachers reflected on the input during the workshops (ED) which led to an enactment on his use of instructional strategies during teaching (DP). He reflected on what was discussed during the classroom and used other strategies like demonstrations and practical experiments besides the normal question and answer as well as discussion methods DC→PD.

4.3.3.2 Knowledge of Topic-specific strategies

This category of PCK refers to teachers' knowledge of specific strategies that are useful for helping students comprehend specific science concepts in a particular topic. The knowledge can be in a form of representations and activities. This includes how to present, unpack and assess the topic at hand. The development of the teachers' knowledge of topic-specific strategies is shown in figure 4.5 below.

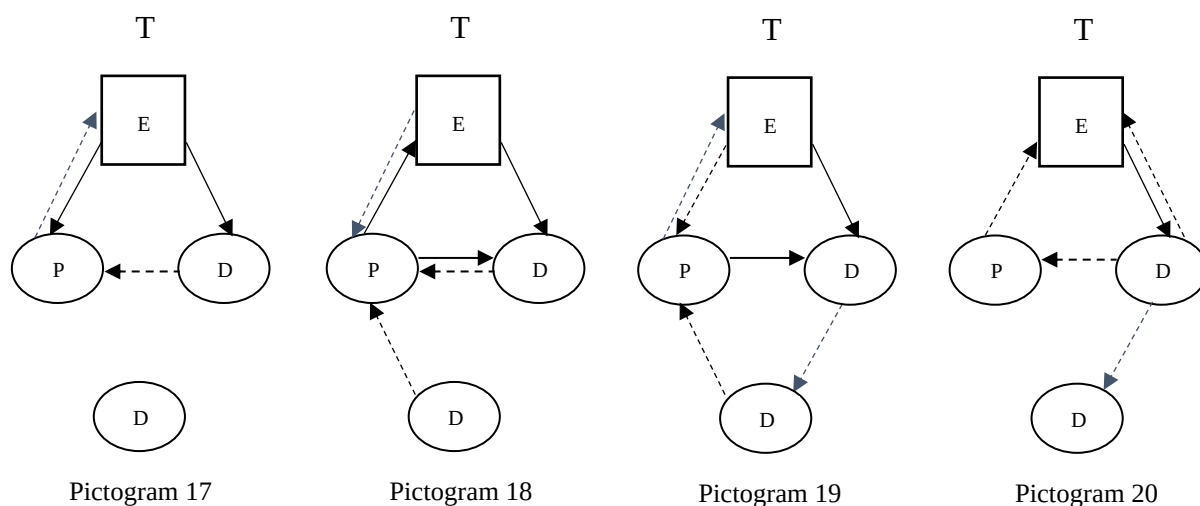


Figure 4.5: The development of teachers' knowledge of Topic-specific strategies

Teacher 1

Figure 4.4 shows a change sequence for T1 in pictogram 17. Although the teacher had knowledge about different instructional tools and was able to apply it in class, there was no visible change in the way the students participated. After performing a demonstration, the students couldn't arrange the equipment to perform experiments. He had insufficient resources for the practical work, and he couldn't improvise.

Teacher 2

In pictogram 18 a growth network is observed with T2 which involved: the ED enactment on the DP; the PD enactment on the DP; the ED enactment on the PD; stimulating a reflection of the DP on the PD as well as the DC on the DP. T2 displayed high knowledge and application of the different instructional tools. He was able to use the textbook, the video clips and material from the subject advisor in his lessons. During the workshops, he assisted other teachers on how to meaningfully improvise as well as use the limited resources at their schools.

Teacher 3

A growth network was observed as the teacher displayed knowledge about different instructional tools. His knowledge of electricity from the university and the internet had an enactment on his DP and was reflected in his PD. The changed PD assisted him to use different tools like textbooks, overhead projector and video clips in the class. That resulted in In pictogram 19 it can be observed that the reflection on the DC by the DP and on the PD by the DC is clearly displayed when the

students' suggested to him other materials to use for electric circuits in case he doesn't have is written in the textbook.

Teacher 4

Pictogram 20 illustrated the following growth network: the teacher's knowledge of instructional tools from university and workshops enacted on his DP. He reflected on the input during the workshops from the other teachers (ED) and came up with new ways to use the various tools in his class (DP). He modified the lesson design from a guided-inquiry to a more open-inquiry after discussing with the other teachers. These reflections led to further changes in his knowledge as he vowed to introduce videos and create whatsapp groups for interaction in his class in future.

4.3.4 Knowledge of students' understanding of science

Knowledge of students' understanding of science refers to the knowledge teachers must have about students' requirements for learning specific science concepts, areas of science that students find difficult and their misconceptions in order to help them develop specific scientific knowledge. This category of the PCK component has been divided into two: knowledge of areas of student difficulty and knowledge of students' misconceptions.

4.3.4.1 Knowledge of areas of student difficulty

Knowledge of areas of student difficulty refers to teachers' knowledge of the science concepts or topics that students struggle to learn. There are several reasons why students find learning difficult in science for example in some science topics learning is difficult because the concepts are very abstract, and other topics are difficult because instruction centres on problem solving however teachers should be knowledgeable about each type of difficulty. Figure 4.6 below shows the development of the teacher's knowledge of the student difficulty to learning.

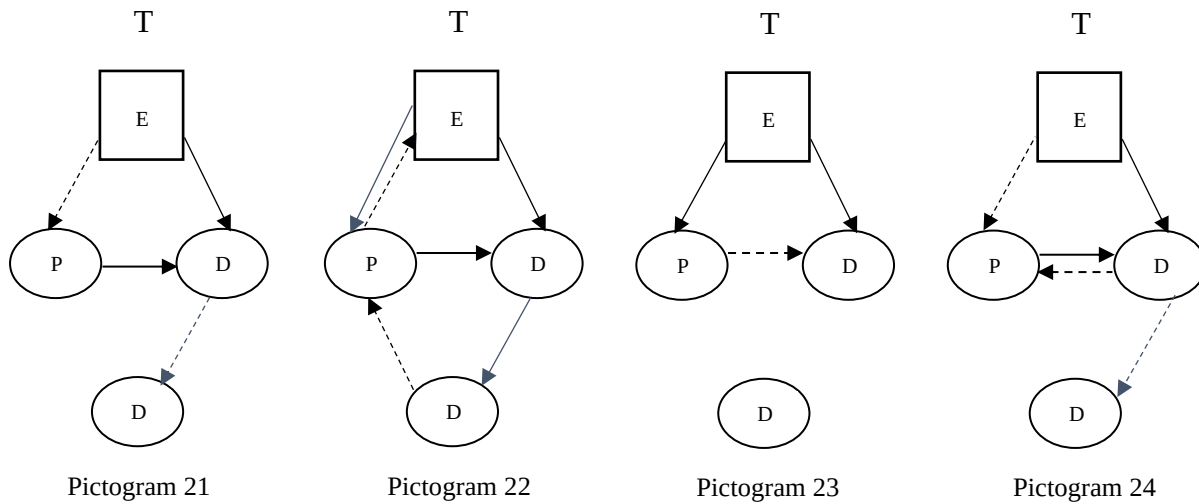


Figure 4.6: The development of teachers' knowledge of areas of student difficulty

Teacher 1

Figure 4.6 depicts a change sequence of the teacher's knowledge of the learners' understanding. The teacher had knowledge about the requirements for student learning and areas of student difficulty but struggled to implement that knowledge. He kept on talking even when it was clear that learners were not following the lesson well just so as he reaches questioning time. It is during the questioning time that he was able to address some of the students' understanding of the concept of electricity. It was only during practical experiments that he acknowledged students' having prior knowledge and trying to address it. The change sequence can be observed in pictogram 21 as: enactment of ED and PD on DP; a reflection on his PD from the DP after the questioning session which stimulated a reflection on the DC.

Teacher 2

A growth network is observed in pictogram 22 for T2. He displayed knowledge of students' understanding of the content, how to perform a certain skill like following laboratory instructions and students' ability to master a skill (ED→DP). He grouped the learners and gave instructions according to their level of understanding (PD→DP). The students were also able to explain to their fellow students during the class to assist them understand the concept of electricity better (DP→DC). He reflected on what was discussed during the classroom and used other strategies to enhance his knowledge of students' understanding for retrieving knowledge as well as their motivation to learn content DC→PD.

Teacher 3

Figure 4.6 shows a change sequence for T3 in pictogram 23. Although the teacher had knowledge about the content, different instructional strategies and tools he did not display knowledge of learners' understanding of the content. No reflection was observed on his PD or DC during the lessons.

Extract 4.9:

T3: What is potential difference?(points at learner 17)

L 17: I don't know sir, actually I don't understand anything.

T 3: What do you mean you don't understand anything? I have been teaching you this for 3 days and today you say you don't understand anything?

L 17: But sir I am being honest, I don't understand. I think the calculations confused me more.

Teacher 4

In pictogram 24 a growth network is observed with T4 which involved: the ED enactment on the DP; the PD enactment on the DP; the ED stimulating a reflection on the PD; reflection of the DP on the PD as well as the DP on the DC. T4 displayed high knowledge of the students' understanding of content. He had knowledge of students' prior knowledge as well as possible difficulties students may experience during learning. He even grouped the learners according to their level of understanding during experiments so that he can spend more time assisting those who have barriers to learning.

4.3.4.2 Knowledge of students' misconceptions

Knowledge of students' misconceptions refers to the type of difficulty students' encounter when learning topic areas or concepts in which their prior knowledge is contrary to the targeted scientific concepts known as misconceptions. These concepts can be difficult to learn because misconceptions are coherent with the student' everyday life experiences and therefore typically favoured over scientific knowledge. Teachers should be knowledgeable about the misconceptions and how to address them. The results are shown in figure 4.7 below.

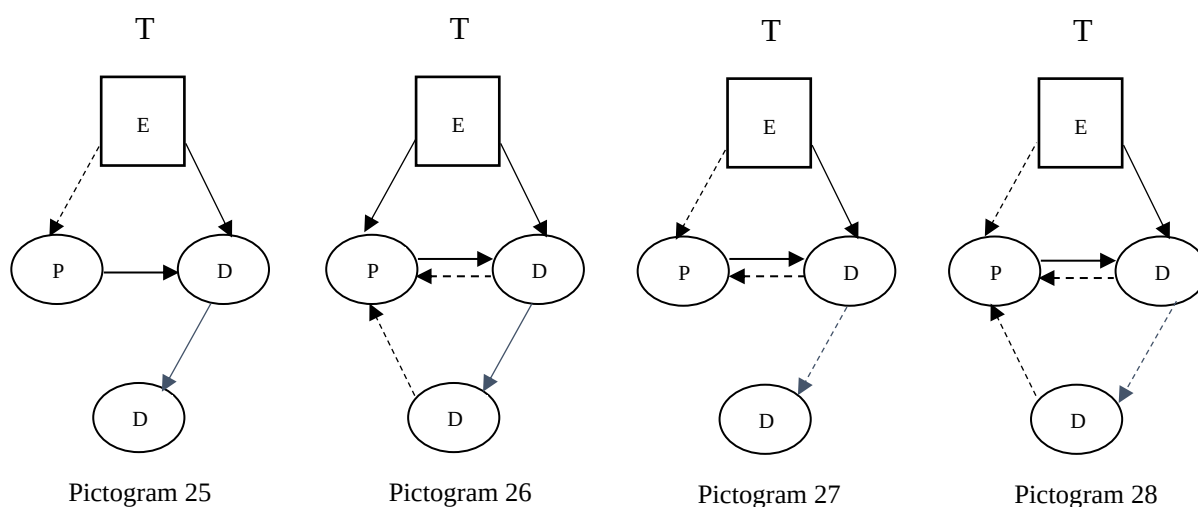


Figure 4.7: The development of teachers' knowledge of students' misconceptions

Teacher 1

A change sequence was observed for T1 in pictogram 25 and showed an enactment of his knowledge from university and workshops (ED), as well as his personal knowledge (PD) of learner misconceptions on his class teaching (DP). He recognized that students were not blank slates and do come in with preconceived ideas to the class. He was aware of students' specific misconceptions on electricity and addressed them at the beginning of the lesson (PD→DP). He matched these students' ideas to a list of commonly known conceptions and developed pedagogical strategies designed to confront and change these ideas (DP→DC).

Extract 4.10:

R: What knowledge about learner thinking influences your teaching of this topic? Indicate the learners' typical misconception(s) on this topic.

T1: You know in the classroom we have to create an environment where students are not afraid to answer, be willing to make mistakes so that their ideas, which may not be correct, will come out and be addressed. Learners have misconceptions about current and potential difference in the circuit. The language used is a contributing factor to their misconceptions.

Teacher 2

T2 displayed knowledge of learners' misconceptions on electricity and tried to address them. He indicated that if the learners have a misconception, they're only going to change most effectively if they're actually able to recognize the difference between what their ideas of how things work and actually seeing it work differently. He showed that if you don't give them an alternative to their idea they will hold onto it and it will affect their learning. He performed an experiment to explain the concept of resistance clearly because most learners believed that if the numbers of resistors in parallel are increased, the total resistance will also increase. The growth network was observed in pictogram 26 and involved: the ED enactment on the DP; the PD enactment on the DP; the ED enactment on the PD; the enactment of the DP on the DC; stimulating a reflection of the DP on the PD as well as the DC on the PD.

Teacher 3

A growth network was observed in pictogram 27 for T3 and involved: the ED enactment on the DP and the PD enactment on the DP. This resulted in the reflection of the DP on the PD as well as stimulating the reflection of the DP on the DC. He highlighted that it is not easy to convince the learners without conducting the experiments with them and the realization and emphasis on the interconnectedness of students' ideas developed a better framework for understanding.

Extract 4.11:

R: What knowledge about learner thinking influences your teaching of this topic? Indicate the learners' typical misconception(s) on this topic.

T3: These learners can have pretty good ideas and still get some of these wrong because they are connecting it to a certain kind of experience which is a misconception. I keep telling them that we do not charge a battery, but they keep on saying that, that's what they know to be true, that's what everyone at home says.

Teacher 4

A growth network was observed as the teacher displayed knowledge about different misconceptions that students held and prior knowledge of electricity in pictogram 28. His knowledge of electricity from the university and the internet had an enactment on his DP and was reflected in his PD. The reflection on his DC assisted him to recognise students' ideas as context-dependent and lacking experiential-based ideas. He conducted an experiment to show that an ideal

battery supplies a constant voltage, not a constant current. The current is the result of the combined effect of the voltage and the effective resistance of the circuit. This means that changing a device in a circuit changes the current while the voltage is unchanged.

4.3.5 Knowledge of Assessment in Science

Knowledge about assessment in science refers to the teachers' knowledge about dimensions of science learning important to assess, and knowledge of the methods and tools by which learning can be assessed. This category of the PCK component has also been divided into two.

4.3.5.1 Knowledge of Assessment methods

This category of PCK refers to teachers' knowledge of different methods that might be employed to assess the specific aspects of student learning for a particular topic. The methods differ according to the content, some are theoretical and others are practical. Figure 4.8 shows the results for the development of teachers' knowledge of assessment methods.

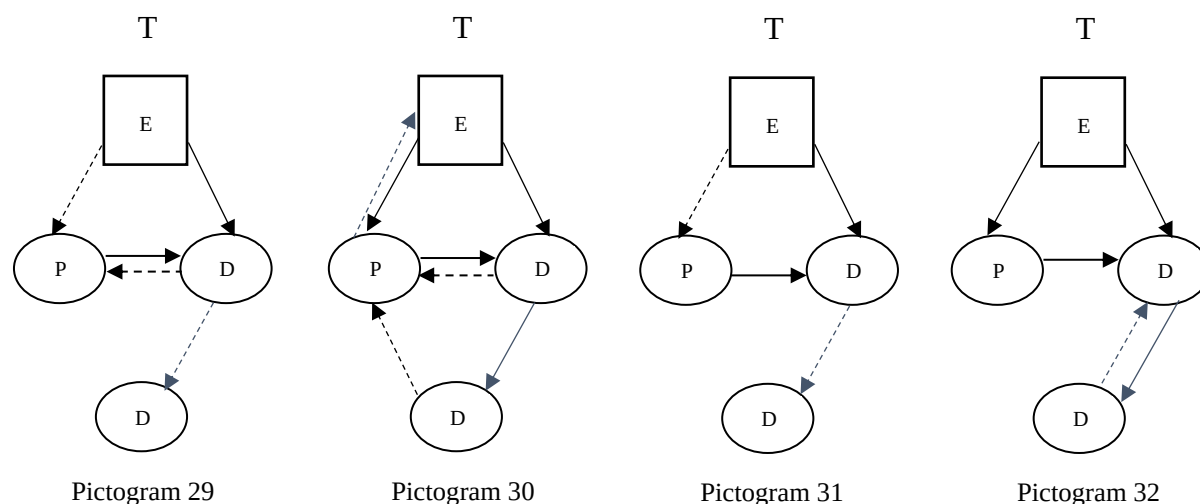


Figure 4.8: The development of teachers' knowledge of assessment methods

Teacher 1

In figure 4.8 a central growth network pattern was observed in pictogram 29 and it involved: the ED enactment on the DP; the PD enactment on the DP; stimulating a reflection of the DP on the PD as well as the DP on the DC. He indicated that interaction with science teachers during the

workshop, attending the professional forum and consultation with his Head of Department helped him understand different assessment methods. He highlighted that not only relying on the traditional question and answer method has also helped him to look at other strategies to teach the electricity topic.

Extract 4.12:

Researcher: Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge?

T1 (Teacher 1): I attended content training workshop on the topic at the beginning of the term. It was developmental unfortunately we did not cover everything because there was no electricity, it was very cold and we had to leave earlier because the venue was not conducive. I was not happy but there was nothing I could do.

Researcher: Did you achieve some of your professional development needs because of the workshops I conducted on this topic?

T 1 (Teacher 1): These were the most developmental workshops that I have ever attended. I can now proudly stand in front of my learners and teach the topic of electricity. I am grateful that I had the opportunity to meet with experienced teachers who were willing to take me by hand to ensure that my knowledge is improved. As a novice teacher I learned different strategies to teach the topic but most importantly I will now be able to apply different assessment methods in my class. I promise you my results will improve going forward.

Teacher 2

T2 displayed knowledge of different assessment methods in science teaching. He was able to impart his knowledge and retrieve the learners' knowledge at the same time through his questioning skill. He gave the learners an opportunity to conduct experiments, write short classwork activities and highlighted that he gives weekly tests to his learners. The growth network in pictogram 30 involved: an enactment of the ED on the PD as well as on the DP; the enactment of the PD on the DP; a reflection of the DP on the PD; stimulating an enactment of the DP on the DC which resulted in the reflection on the PD.

Teacher 3

A change sequence is observed in pictogram 31 for T3. Although he had knowledge of different assessment methods from the university and through his teaching experience (ED), he struggled

to implement them in class. He used classwork and homework as his assessment method and they were just informal assessment. Learners marked each other's books whilst he wrote the correct answers on the chalkboard. However, based on the different instructional methods he applied there was a reflection from his PD on his DP which resulted in a reflection on the DC.

Teacher 4

In figure 4.8 a central growth pattern was observed in pictogram 32 and it involved: the ED enactment on the DP; the PD enactment on the DP; leading to an enactment of the DP on the DC and stimulating a reflection of the DC on the DP. He indicated that interaction with science teachers during the workshop, attending the professional forum and consultation the internet has helped him understand different assessment methods and be able to apply them. He highlighted that not only relying on the traditional question and answer method has also helped him to look at other strategies like investigations and tutorials to teach the electricity topic.

Extract 4.13:

Researcher: Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge?

T4 (Teacher 4): Yes I attended content training workshop on the topic. I learned a lot, how to approach different concepts especially division of current and resistance which I struggled with but was not satisfied because the time allocated was very little.

Researcher: Did you achieve some of your professional development needs because of the workshops I conducted on this topic?

T 4 (Teacher 4): Shuu, I have never attended workshops so informative and developmental like these before, thank you very much. The other teachers were amazing, I didn't think I will enjoy teaching and be able to simply electricity to my learners until now. I learned different strategies to teach the topic, assess the learners and which instrument to use. At least I have confidence to perform demonstrations, practical experiments and assess them. I promise you I will apply all the methods I learned in my science teaching, no more homeworks and tests only.

4.3.5.2 Knowledge of topic-specific assessment instrument

Knowledge of topic-specific assessment instrument refers to the knowledge about the specific tools to use during assessment. In science, they can include rubrics, observation sheets, question papers, portfolio of evidence and many more others. The teacher should know which instrument

to use when applying a particular method for assessment. The results are shown in figure 4.9 below.

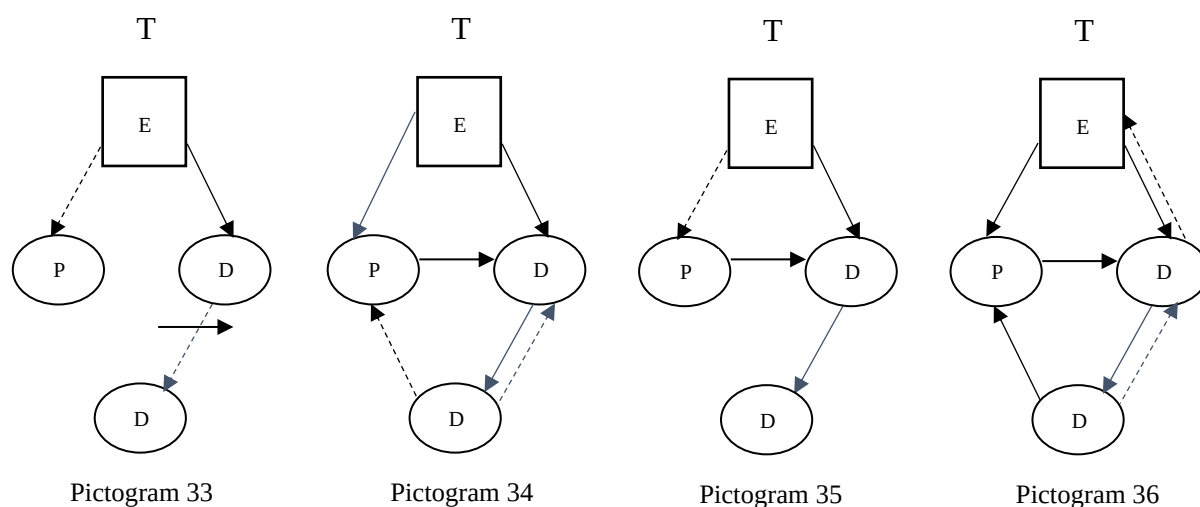


Figure 4.9: The development of teachers' knowledge of topic-specific assessment instruments

Teacher 1

In the extended model of figure 4.9, pictogram 33, a change sequence was observed in which no one relationship predominated during the development of a teacher's knowledge of assessment instruments. It involved: the enactment of the ED on the DP as well as the PD on the DP through his knowledge of different assessment instruments. He was not able to administer them all as expected, especially the rubric and the observation sheet during the experiments. However, when learners realised that he is individually assessing them even though they were in groups they became more attentive and serious, a reflection of the DP on the DC.

Teacher 2

A growth network was observed in pictogram 34 on the teacher's knowledge of assessment instruments and involved: enactment of the ED on the PD and the DP due to his pedagogical content knowledge, experience and collaboration with other teachers during workshops. This stimulated the enactment of the PD on the DP; leading to an enactment of the DP on the DC. He displayed knowledge of checklists for performing a laboratory experiment, observation sheets and setting of quality questions for the classwork activity.

Teacher 3

Pictogram 35 shows a change sequence was observed in which no one relationship predominated during the development of a teacher's knowledge of assessment instruments. In this case, the way the teacher understood the assessment instruments in the ED during the workshop and professional teacher forums enacted on his DP as well as stimulating a reflection on his PD. He was able to use observation sheets during the practical experiments and set questions for homework.

Teacher 4

In figure 4.9 a growth network was observed in pictogram 36 on the teacher's knowledge of assessment instruments. His knowledge from the university, internet and workshops (ED) had an enactment on the PD and the DP. The changed DP had an enactment on the PD, he was able to change his questioning style after realising that learners struggle to understand as a result, they copy from each other or do not write anything at all.

4.4 Discussion of findings

The previous sections presented findings; however, this section discusses the presented findings in the order the PCK components were presented.

4.4.1 Orientations towards teaching science

As mentioned earlier, orientations towards teaching science refers to the teachers' views of knowledge; their teaching methods; context dependent information on content, beliefs about the purposes and goals of teaching science (Hewson & Hewson, 1988; Hewson et al., 1999). Wongsopawiro et al. (2017) states that teachers might improve their teaching practice resulting in better student outcomes when they change their beliefs, and attitudes. This suggests that teachers' orientations are an important part of science teaching. The findings of this study regarding this component revealed that teachers displayed meaningful patterns of information on their goals for science teaching. It was also found that teachers' pedagogical orientations are influenced by learners' practices and behaviour. The finding above corroborates what Mavuru and Ramnarain (2017) found out in their study that teachers' pedagogical orientations are influenced by learners'

socio-cultural practices, experiences and beliefs. The interview with one teacher corroborates the above finding when he said “I have learned from my students that peer learning is important and I should not only teach for results”. It is interesting to note that in all four cases of this study, teachers had positive beliefs and this influenced their classroom practice. There was a shift in the classroom from exclusively teacher-centred to more student-centred approach in teaching electricity. This is in contrast to earlier findings by Chan (2010) that positive teacher beliefs did not influence their choice of pedagogical strategies nor influence their classroom practices.

4.4.2 Knowledge of Science Curriculum

Knowledge of the science curriculum refers to teachers’ being aware of the elements of the science curriculum; variety of instructional tools presented in the science curriculum and how to use them and knowledge about the topic at hand. Tshiredo (2013) reports that looking specifically at the changes that took place in the South African school curriculum especially (CAPS), one can anticipate a different impact of curriculum change in teaching and learning of science in schools. Wood (2016) also states that for teachers to be able to teach and promote learning by students they must have specific knowledge of a subject. The results of this study indicate that teachers displayed a high knowledge of science curriculum and developed content knowledge. Contrary to findings by Moodley (2013) that concepts such as potential difference, current and resistance are abstract by nature and not easy to explain, the teachers in this study were able to explain and make learners understand them. Another interesting finding was that teachers’ knowledge of science curriculum and topic-specific content improved during the intervention workshops. This finding corroborates findings by Dudu (2016) that professional development intervention addressed content knowledge gaps, didactics and pedagogy to improve teacher effectiveness to a larger extent. These results contradict findings by Villegas-Reimers (2003) that workshops appear to yield nothing meaningful since they are unlikely to improve the teaching prowess of the participants.

4.4.3 Knowledge of instructional strategies

Knowledge of instructional strategies covers knowledge of both subject-specific and topic specific teaching strategies. The teacher should be able to use appropriate activities in instruction, use real life examples and analogies in instruction and make use of different representations in instruction.

Mavhunga and Rollnick (2013) in their study found that there is a reciprocal relationship, between PCK and pedagogical transformations evident in the significant improvement in the understanding of content knowledge in the topic. The findings of this study are consistent to that of Mavhunga and Rollnick (2013) in the sense that teachers were able to use a variety of instructional strategies in their classrooms. They designed teaching materials different which enabled them to teach electricity according to their school context. Bizimana and Orodho (2014) revealed that the challenges of availability and adequacy of learning resources was found to negatively affect teacher effectiveness in the use of teaching methods as well as focus on individual learner.

In this study, it was found that the teachers did not have all the necessary resources they needed to teach electricity and conduct practical work as a teaching strategy including laboratories, science equipment, and specimens. However, the teachers were able to improvise, buying some equipment and even asking the learners to bring some materials from home like copper wires, card boxes and batteries to perform experiments except T1 who only relied on the textbook. An interesting finding of this study is that teachers' knowledge of instructional strategies and approaches as well as tools to use in teaching was enhanced during the workshops as professional development interventions. This finding contradicts the results by Pretorius, De Beer and Lautenbach (2014) that professional development interventions in South Africa do not always address teachers' needs or necessarily result in better realisation of outcomes in science.

4.4.4 Knowledge of Students' understanding of Science

Knowledge of students' understanding of science refers to the knowledge teachers must have about students' requirements for learning specific science concepts, areas of science that students find difficult and their misconceptions in order to help them develop specific scientific knowledge. Beni, et al (2012) purports that successful teaching requires that teachers make sense of their students' ideas and respond to unexpected events in the classroom environment. The study by Ndlovu, Amin and Samuel (2017) revealed that there were gaps in the teachers' SMK with the main challenge being their inability to analyse and interpret learners' errors for diagnostic purposes. In this study, contradicting results are revealed in terms of teachers being aware of students' differing needs and ability to respond to them appropriately. Two teachers were aspects of electricity which learners found difficult to learn like resistance and conducting practical experiments and were able to group learners and give them instructions according to their level of understanding. Other teachers could not make sense of their students' ideas and areas of difficulty, corroborating findings by Ndlovu, Amin and Samuel (2017). This discrepancy may be due to the

teachers' experience in teaching science and pedagogical content knowledge. Interestingly the teachers indicated that they were willing to change the instructional strategy and tools to suit the learners, corroborating what was stated by Van Driel & Berry (2010) that instruction can only be effective if it is attuned to the ways in which students learn specific content.

The findings from this study are in line with Mackay and Hobden (2012) who reported that to gain insight into the learners' misconceptions regarding basic circuit electricity, their circuit and wiring diagrams are useful. Although the teachers acknowledged that learners have misconceptions regarding basic electricity circuits, they could not convince them otherwise without conducting demonstrations and practical experiments. Moodley (2013) reports that a number of studies were conducted to find common misconceptions in circuits by learners and it was found the same misconceptions existed. This is corroborated by the finding in this study that the learners still believe that power supply provides constant current regardless of how the circuit is changed.

4.4.5 Knowledge of assessment in science

Knowledge about assessment in science refers to the teachers' knowledge about dimensions of science learning important to assess, and knowledge of the methods and tools by which learning can be assessed. Nzoka and Orodho (2014) assert that good teachers are skilled not only in instructional methods, but also in evaluation and assessment practices that allow them to gauge individual student needs. Teachers should have expertise with aligning curriculum to assessment and keeping subject matter aligned to intended curriculum and without adequate experience in the subject this often proves to be difficult.

The findings of the current study do not support the previous research findings by Menoe (2005) that in most South African classrooms teaching is teacher-centred with an emphasis on lecturing, question and answer exchange, written exercises and tests and very few learner discussions and practicals. In this study, learners were allowed to conduct experiments, work in groups and also ask the teachers questions for clarity. Gunstone (2008) argues that less emphasis is put on practical work and conceptual understanding but is rather focused on calculations. Contrary to this finding, the teachers in this study used practical work as an assessment method more than classworks focusing on calculations. This finding also corroborate what was revealed by Millar (2011) that practical work is widely and frequently used in the teaching of science since it can be both affective and effective in terms of students' learning and enjoyment of science. It is found that teachers in

this study were able to use different assessment tools including rubrics, checklists for performing a laboratory exercise, classworks and tests. Their choice of assessment tools was based on their knowledge of instructional strategies and knowledge of assessment methods.

Table 4.1: Identification of the teachers' change for each of the aspects

Aspect	T1	T2	T3	T4
Orientations to science	CS	GN	GN	CS
Knowledge of curriculum				
Specific curricular content	GN	GN	GN	CS
Topic specific terminology	GN	CS	GN	GN
Knowledge of instructional strategies				
Subject-specific strategies	GN	GN	GN	GN
Topic-specific strategies	CS	GN	GN	GN
Students' understanding of Science				
Areas of student difficulty	CS	GN	CS	GN
Students' misconceptions	CS	GN	GN	GN
Assessment in Science				
Assessment methods	GN	GN	CS	GN
Topic-specific assessment instruments	CS	GN	CS	GN

4.4.6 Changes in teachers' PCK

This study set out with the aim of assessing the Grade 9 Natural Science teachers' PCK of the topic - Electricity. A major question in teacher change literature remains, "how changes in knowledge, beliefs, and attitudes relate to changes in teacher practice?" (Wongsopawiro et al., 2017). According to Tam (2015), teacher change comprises changes that involve both cognition and action. In this study, the Interconnected Model of Teacher Professional Growth (IMTPG) developed by Clarke and Hollingsworth (2002) was used as the basic framework for the establishment of the relationships between the different data gathered in characterising teachers' PCK of electricity. For each teacher, the relationships established between the four domains in relation to each of the nine aspects, reflecting a change sequence or growth network are presented in the table 4.1.

4.5 Summary

In this chapter I presented data, analysed and interpreted it for exploring the teachers' PCK of electricity. The IMTPG model was used as an analytical tool and without it I could have categorised all nine aspects of teachers' knowledge but would have lacked a framework to monitor and understand the development of these knowledge aspects. The four domains of the IMTPG and the subsequent establishment of relationships between these distinct domains which were displayed in the form of pictograms, made it possible to analyse the data for each knowledge aspect in a way that promoted the researcher's understanding of the processes of development of each teacher's knowledge. By identifying relationships between the four domains, using arrows to show the relationships; the IMTPG made it possible for the researcher to understand each teacher's development in a detailed way. In most of the PCK components, the entry points were in the External Domain which highlights the impact of the development workshops conducted during data collection. Clarke and Hollingsworth (2002) used the term 'change sequence' when a single relationship existed between the domains and was superficial, and 'growth networks' when more than two relationships exist between different domains. They stated that 'growth networks' demonstrated professional growth and reflected ongoing and lasting changes. Most of the teachers' knowledge of PCK aspects showed a growth network pattern. In the next chapter, summary of findings, recommendations and conclusions are presented.

CHAPTER 5: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The purpose of this study was to explore Grade 9 Natural Science teachers' PCK of the topic - Electricity. It looked at teachers' orientations to science teaching, their Subject Matter Knowledge (SMK) and Topic Specific Pedagogical Content Knowledge (TSPCK) and implementation of Grade 9 Natural Sciences (NS) CAPS curriculum. The study employed an interpretive, qualitative, multiple case study to generate data. Data were collected by means of workshops, classroom observations and semi-structured interviews. An intervention was conducted with the hope of strengthening the teachers' PCK of the topic - Electricity. Qualitative data were inductively analysed using the IMTPG model and components of PCK according to Magnusson et al. (1999). In this chapter, I thus present a summary of my findings in relation to my three research sub-questions. Moreover, limitations, conclusion and recommendations for this study are also presented.

5.2 Summary of findings

Data generated were analysed to answer my three research sub-questions and I thus present the summary in relation to these research questions.

5.2.1 Research sub-question 1: How does the Grade 9 Natural Sciences' teachers' pedagogical content knowledge manifest during a proposed intervention?

In this study, a workshop as a professional development intervention was purposefully constructed as a learning opportunity for science teachers. Two workshops were conducted and the objectives were: to ensure that teachers are able to explain and demonstrate an understanding of basic Electricity concepts (components of a circuit, current, resistance, series and parallel connections); to be able to use appropriate and relevant methods to teach basic electricity concepts; to acquire knowledge on conducting practical experiments on electrical circuits and how to employ various teaching and assessment strategies on the topic - Electricity. The workshops focused on important content and attended to the context that supports and guides teacher learning. The study revealed

that teachers' pedagogical content knowledge, knowledge of science curriculum and topic-specific content improved during the intervention workshops, corroborating earlier findings by some researchers (Dudu, 2016; Ndlovu, Amin & Samuel, 2017). An interesting finding of this study is that teachers' knowledge of instructional strategies and approaches as well as tools to use in teaching was enhanced during the workshops as professional development interventions. This finding is contrary to the argument by some researchers (Feiman-Nemser, 2001; Villegas-Reimers, 2003) that the workshops appear to yield nothing meaningful since they are unlikely to improve the teaching prowess of the participants. For example, teacher 4 (T4) indicated that interaction with science teachers during the workshop and attending the professional forum and using the internet search engines have helped him understand different assessment methods and be able to apply them. During the workshops, T2 displayed a high knowledge and understanding of the electricity topic and assisted other teachers on how to meaningfully improvise as well as use the limited resources at their schools as well as how to tackle learners' misconceptions. The engagement in activities stimulated the development of both subject matter knowledge and PCK of the participants. During the intervention, the teachers designed teaching materials different from the ones stated in the textbooks which enabled them to teach the topic -Electricity according to their school context.

5.2.2 Research sub-question 2: How does the teachers' orientation to science teaching influence their pedagogical content knowledge?

Magnusson et al. (1999), refer to teachers' knowledge and beliefs about the purposes and goals of teaching science as teacher orientations. Van Driel and Abell (2011) argue that when teachers change their knowledge, beliefs, and attitudes on, their teaching practice will improve and accordingly result in better student outcomes. The findings of this study regarding this component revealed that teachers displayed meaningful patterns of information on their goals for science teaching. It was also found that teachers' pedagogical orientations are influenced by learners' practices and behaviour. Teacher 2 (T2) for example, explained that, "I have learned from my students that peer learning is important and I should not only teach for results". Teachers displayed different orientations to science teaching; discovery, didactic, conceptual change, activity driven and also guided discovery. This finding indicates a development in the teachers PCK which is consistent with that of Goodnough and Nolan (2008) which states that a constructivist orientation of a teacher helps to focus on the learning of the students and therefore a rich PCK can be

developed. Learners were given materials to construct electrical circuits, asked questions on electricity concepts, allowed to discover what they can about electrical phenomena through pursuing their own questions. For teachers T1 and T3 the lessons ended up shifting from exclusively teacher-centred to more student-centred approach in teaching electricity contrary to findings by Chan (2010). T1 in his closing remarks on the last day of the workshop commented, “I have always been chasing the annual teaching plan, leaving most of my learners in the dark and as a result labelling them as stupid. I can now confidently allow them to conduct experiments and not do demonstrations for them. Learning science is going to be fun going forward.” The teachers’ pedagogical orientations are influenced by learners’ practices and behaviour.

5.2.3 Research sub-question 3: In what ways do specific characteristics of the professional development programme contribute to shifts in the teachers’ PCK?

The study reveals positive shifts in the teachers’ PCK during and after the professional development intervention. The PDP was planned by the researcher and included setting goals, planning, enacting and reflecting on the entire process. It focused on important content and context that supports and guides teacher learning. From the study, it emerged that collaboration is important in supporting teacher growth. The teachers reinforced, expanded, and challenged their notions about teaching science and their PCK. The teachers’ interaction during the intervention showed that they enjoyed focusing on content knowledge and instruction, and there was an improvement in certain areas of their pedagogical content knowledge. This finding is in support of Clarke and Hollingsworth’s (2002) argument that participants should be afforded the opportunities to enact change in a variety of forms during professional development programmes. It was observed that T1 at first seemed to lack underlying knowledge of science curriculum and limited applicability but delivered the lesson with confidence after the second workshop. The finding corroborates those by Guskey (2002) every time a lesson is taught, a curriculum designed, an assessment administered, teachers learn.

During the workshop, it became clear that teachers need to engage in professional development activities in order to improve their instructional practice and student learning since Content knowledge is an important component of a professional development programme (PDP). For example, T1 struggled to perform experiments in his class due to lack of resources. However, after the workshop he became more innovative to conduct experiments and also enhanced his content

knowledge of the topic - Electricity. It also reinforces the idea that PDPs are essential in improving teachers' classroom instruction. Another important finding was the enactment of the teachers' classroom instructional practices. It was evident that the teachers' beliefs and school environment influenced the way they implemented the standards-based instructional strategies. Although the teachers complained about the time normally allocated for PDPs, they were satisfied that in this instance it was adequate for them to learn a lot on electricity.

5.3 Limitations of the study

The use of purposive sampling of four Grade 9 Natural Science teachers in four secondary schools, in one district of the whole province weighs heavily against the generalizability of the findings of this research. This is a comparatively small sample size looking at the number of secondary schools as well as number of Grade 9 teachers in South Africa. A greater sample size is more representative of the population and increases the credibility of the research results (McMillan & Schumacher, 2010). However, given that the study was more on establishing deep insights regarding the issue at hand, generalizability was relegated to the doldrums as a goal for this study. The study was also conducted in rural schools which have consistently experienced poor learner performance in Natural Sciences hence schools with a similar performance background might find the study findings informative. Though the study sought to explore teachers' PCK of the topic - Electricity due to poor performance experienced, it could not explain the positive responses by the teachers contradicting the phenomenon under scrutiny. This might be due to the fact that all the teachers were relevantly qualified to teach Grade 9 Natural Sciences.

The other weakness was that the teachers sampled also taught Grade 12 and were busy preparing for preparatory examinations and Continuous Assessment (CASS) moderations. Although they had agreed to participate in the study and did not miss the intervention workshops, their attention was divided. Lastly but not least, I had anticipated a delay in the granting of permission to conduct the research in the schools due to bureaucratic processes, and it was as such but eventually permission was granted by the relevant offices.

5.4 Recommendations

Based on the above findings, this study recommends that:

- Teachers be taken through interventions for professional development programmes at the beginning of each term to enhance their pedagogical content knowledge. These interventions should be well planned and allocated enough time to run.
- Teachers should be provided with resources to teach science especially laboratory equipment since it is a practical subject. It is easier for teachers to address learners' misconceptions by performing experiments which contradicts their prior knowledge.
- Teachers' orientations to science teaching and content knowledge be taken into consideration when developing the curriculum as well as professional development programmes. This was found to be a challenge since teachers rush to cover the Annual Teaching Plan (ATP) hence classrooms activities are teacher- orientated.
- Although the teachers were relevantly qualified, some could not transfer their knowledge to the learners. This calls for more teacher support, including formation of Professional Learning Communities to share good practices and form collaborations.
- The allocation of Grade 9 teachers be done in a manner that it will not compromise teaching during Grade 12 activities due to sharing of teachers.

5.5 Areas of future research

An investigation into factors contributing to poor learner performance besides teachers PCK is needed. More studies should be conducted in order to curb this challenge and ensure that South Africa has adequately prepared and knowledgeable future scientists. It will be also interesting to find out what the results could be if the study was conducted with a larger sample across all the districts.

5.6 Conclusion

The focus of this study was on investigating the Grade 9 Natural Science Teachers' PCK of electricity. The findings of this study have an important implication for the development of the teachers' PCK and implementing it in classrooms. Researchers agree that PCK is a useful construct, however it is not easy to find out exactly what it comprises and then use this knowledge to devise good practice in teacher education. The IMTPG model was used as an analytical tool and assisted me to categorise all nine aspects of teachers' PCK and also to monitor and understand the development of these knowledge aspects. In most of the PCK components, the entry points were

in the External Domain which highlights the impact of the development workshops conducted during data collection. Most of the teachers' knowledge of PCK aspects showed a growth network pattern.

The findings of this study regarding this component revealed that teachers displayed meaningful patterns of information on their goals for science teaching. It was also found that teachers' pedagogical orientations are influenced by learners' practices and behaviour. As revealed by the findings, teachers' pedagogical content knowledge, knowledge of science curriculum and topic-specific content improved during the workshop as a professional development intervention. Also their knowledge of instructional strategies and approaches as well as tools to use in teaching was enhanced during the workshops. The results of this study indicate that teachers displayed a high knowledge of science curriculum and developed content knowledge even though their learner performance is very poor (below 30%) in Natural Sciences. Lack of resources remain a serious challenge in most schools and this impact negatively on the teaching and learning of science. The study revealed that some teachers could not make sense of their students' ideas and areas of difficulty, posing a challenge on how to implement their subject matter knowledge. It is clear that being academically well-qualified does not guarantee that the teacher will teach that subject effectively. In conclusion, teachers responded positively to the intervention and this shows a need for more of such workshops as well as Professional Learning Communities for support and sharing of good practices.

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APPENDICES

APPENDIX A: ETHICS APPROVAL LETTER

24879436@nwu.ac.za
Per e-mail



Private Bag X6001, Potchefstroom,
South Africa, 2520

Tel: +27(18) 299-1111/2222

Web: <http://www.nwu.ac.za>

Human Resource Research Ethics Committee

Tel: 018 289 2044

Email: Betchani.Tchereni@nwu.ac.za

Dear DR WASHINGTON TAKAWIRA DUDU

20-Nov-2017

APPROVAL OF ETHICS APPLICATION: NWU-HS-2017-0223

The following application has been reviewed by the Human Resource Research Ethics Committee (HRREC) on 14-Nov-2017.

Name of student: J G Poti - 12021962.

Name of supervisor/promoter: DR WASHINGTON TAKAWIRA DUDU.

Title of study: Exploring Grade 9 Natural Science Teachers' Pedagogical Content Knowledge of Electricity in Moses Kotane Area Office, North West Province.

Application Risk Level: .

This letter serves to inform you that your application has been approved from 14-Nov-2017 to .

Special conditions of the approval (if applicable):

Yours Sincerely

A handwritten signature in black ink, appearing to read 'B. Tchereni', with a stylized flourish at the end.

Prof B. Tchereni

Chairperson: Human Resource Research Ethics Committee (HRREC)

APPENDIX B: APPLICATION TO CONDUCT RESEARCH



Education and Sport Development

Department of Education and Sport Development
Departement van Onderwys en Sportontwikkeling
Lefapha la Thuto le Tlhabololo ya Metshameko

NORTH WEST PROVINCE

Mogwase Shopping Centre,
Old Mutual Wing, Room 9, Mogwase 0314
Private Bag X1003, Mogwase 0314
Tel.: (014) 555-6170/7
Tel.: (014) 555-6183
Fax: (014) 555-6171
e-mail: dkekae@nwpg.gov.za

OFFICE OF THE SUB-DISTRICT MANAGER: MOSES KOTANE BOJANALA DISTRICT

Enq : Poti J.G

Tel : 0145556171/0769722019

To : Mrs. SM Semaswe

Superintendent- General (NWDoE)

From : Ms. JG Poti

Date :

REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN SCHOOLS

I, Poti Joyce Godisamang, am a Master's degree registered student (12021962) at North-West University (Mafikeng Campus). I hereby request for permission to conduct a research study in Moses Kotane East Area Office in Bojanala District. The title of my thesis is: ***Exploring Grade 9 Natural Science Teachers' Pedagogical Content Knowledge of Electricity in Moses Kotane Area Office, North West Province***. I will be collecting data through classroom observations, semi structured interviews as well as intervention workshops with the sampled teachers. I will ensure that there will be no disruption of teaching and learning during data collection.

Participation in the study is voluntary and participants as well as their schools will be kept anonymous. Should you enquire more information about the project, kindly contact my supervisor for this project at the university: Prof. Washington T. Dudu (+27 18 389 2833).

Thanking you in anticipation.

Yours faithfully

.....

Poti J.G.

APPENDIX C: APPROVAL TO CONDUCT RESEARCH FROM HEAD OFFICE



Education and Sport Development
Department of Education and Sport Development
Departement van Onderwys en Sportontwikkeling
Lelaphe la Thuto le Tšhabololo ya Metshameko
NORTH WEST PROVINCE

Gerona Building, Mmabatho
1st Floor, East Wing
Private Bag X2044,
Mmabatho 2735
Tel.: (018) 300-3433
Fax.: 086-514-6128
e-mail: mothebane@nwpp.gov.za

OFFICE OF THE SUPERINTENDENT-GENERAL

Enq. : Dr TA Phorabatho
Tel. : 018 388 3429/3433/3071

To: Ms J.G. Poti
Moses Kotane Sub-district
Bojanala District

From : Mrs. SM Semaswe
Superintendent-General

Date : 06 June 2018

PERMISSION TO CONDUCT RESEARCH: MS JG POTI

Permission is hereby granted to you Ms. Joyce Godisamang Poti to conduct research in the department as requested, subject to the following conditions:

- You contact the relevant School Principals for your target schools about your request with this letter of permission.
- Considering that your research will involve both Educators and Learners, the general functionality of the school should not be compromised by the research process.
- The participation in your project will be voluntary.
- The principles of informed consent and confidentiality will be observed in strictest terms, and
- The findings of your research should be made available to the North West Department of Education and Sport Development upon request.

Best wishes

Mrs S M Semaswe
Superintendent-General



"Towards Excellence in Education and Sport Development"

APPENDIX D: REQUEST LETTER TO PRINCIPALS



Education and Sport Development

Department of Education and Sport Development
Departement van Onderwys en Sportontwikkeling
Lefapha la Thuto le Tlhabololo ya Metshameko
NORTH WEST PROVINCE

Mogwase Shopping Centre,
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Fax: (014) 555-6171
e-mail: dkekae@nwpg.gov.za

OFFICE OF THE SUB-DISTRICT MANAGER: MOSES KOTANE BOJANALA DISTRICT

Enq : Khunou N
Tel : 0145556170/1
Email : NKhunou@nwpg.gov.za

DATE : 22 JUNE 2018

FROM : Mr DM Kekae
Moses Kotane Sub District Manager

TO : Moses Kotane Schools Principals

**SUBJECT: PERMISSION TO CONDUCT RESEARCH IN MOSES KOTANE AREA
OFFICE**

This serves to inform you that **Ms. J.G Poti** who is a **Master's student at North West University (Mafikeng Campus)** has requested for permission to conduct research in Moses Kotane secondary schools and it has been granted. You are therefore requested to assist her in this regard so as to complete her studies.

Ms Poti does have an understanding that the collection of data is subject to the following conditions:

- that it should not interfere with teaching and learning at schools;
- and that the Department will receive a final copy of the research and summary of the research findings be made available.

Hope you will find this in order.

Yours in education

.....

Mr Kekae D.M (Sub-District Manager)

APPENDIX E: REQUEST TO PARTICIPATE IN THE STUDY - TEACHERS

P.O. BOX 6267
RUSTENBURG
0300
27 JUNE 2018

The Teacher
Moses Kotane East Area Office
Bojanala District
North West Province

Dear Sir/Madam

REQUEST FOR PARTICIPATION TO THE STUDY

I am Joyce Godisamang Poti, a Master's degree registered student (12021962) at the North-West University, Mafikeng Campus. I am hereby kindly requesting you to participate in my research. The title of my dissertation is: ***Exploring Grade 9 Natural Science Teachers' PCK in the Teaching of Electricity in Moses Kotane Area Office, North West Province.***

I will be collecting data through classroom observations, semi structured interviews as well as intervention workshops and I wish you to participate in them all. Collection of data (interviews) will occur outside school contact time so as not to interfere with teaching and learning responsibilities, however the workshops and classroom observations will take place during teaching time as this data needs real life situation.

Your participation will be voluntary and your identity will be kept anonymous at all times. Should you enquire more information about the project, kindly contact my supervisor for this project at the university: Prof. Washington T. Dudu (+27 18 389 2833). It would be appreciated if you would kindly grant **written** permission. The consent form is herewith attached for you to please sign.

Yours sincerely



.....
Poti J.G.

APPENDIX F: CONSENT FORM FOR TEACHERS

TEACHERS' INFORMED CONSENT FORM

Research Project Title:	Exploring Grade 9 Natural Science Teachers' PCK in the Teaching of Electricity in Moses Kotane Area Office, North West Province.
Researcher:	Ms Poti Joyce Godisamang
Supervisor:	Prof. WT Dudu
Participation information	
• I understand the purpose of the research study and my involvement in it; • I understand the risk and benefits of participating in this research study; • I understand that I may withdraw from the research study at any stage without and penalty; • I understand that while information gained during the study may be published, I will remain anonymous and no reference will be made to me by my name or student number; • I understand and agree that the interviews will be recorded electronically; • I understand that data collection requirements particularly to this research, (e.g. test results, personal information, video recording) may be used; • I understand that I will be given the opportunity to read and comment on the transcribed interviews notes; • I confirm that I am not participating in this study for financial gain.	
Information Explanation	
The above information was explained by: <u>Poti Joyce Godisamang</u> (Researcher)	
Voluntary Consent	
I, _____ Hereby voluntarily consent to participate in the above-mentioned research.	
Signature: _____	Date: / /

APPENDIX G: CONSENT FORM FOR PARENTS

P.O. BOX 6267
RUSTENBURG
0300
01 JULY 2018

The Parent
Moses Kotane East Area Office
Bojanala District
North West Province

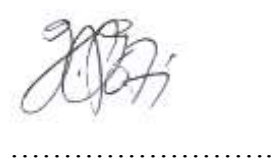
Dear parent

My name is Poti Joyce Godisamang, currently registered as a Master's degree student (12021962) at North West University, Mafikeng Campus. I am carrying out a research study together with Grade 9 Natural Science teachers in the Moses Kotane East Area Office. Your child's Natural Science teacher is participating in this study and I am going to observe this teacher's lesson twice, to investigate *his PCK in the Teaching of Electricity in grade 9*.

Possibly, some of the science lessons will be recorded however all information will be treated with confidentiality. There is no foreseeable risk involved in your child participating in the research activities named above. Please note that all participation is voluntary and should you not wish for your child to participate he/she will not be included. Also, you are free to withdraw your permission at any time without giving a reason.

Should you enquire more information about the project, kindly contact me on 0769722019 or my supervisor for this project at the university: Prof. Washington T. Dudu (+27 18 389 2833). Thank you for taking time to read this letter. If you agree for your child to participate in this research, please complete the consent form below.

Yours sincerely



Ms Poti Joyce G.

North West University: M.Ed in Science Education Student

REPLY SLIP FOR PARENT'S/GUARDIAN'S

I _____(full name of parent/guardian), the father/mother/guardian of _____(full name of child) hereby confirm that understand the content of this document and the nature of the research, and I consent to my child participating in the research study. I also understand that my child is at liberty to withdraw from participating at any time without any disadvantage.

I agree and authorise my child to participate in the research and I understand that my child can withdraw from participating without any effect.

Parent's/Guardian's full name _____

Parent's/Guardian's Signature _____ **Date** _____

Contact numbers _____

APPENDIX H: PROFESSIONAL DEVELOPMENT INSTRUMENT

Topic: Exploring Grade 9 Natural Science Teachers' Pedagogical Content Knowledge of Electricity in Moses Kotane Area Office, North West Province

Professional Development Programmes (Workshops)

This document provides a general overview of the workshops that will be conducted as professional development programmes aimed at assisting educators to effectively teach the topic on Electricity for grade 9 learners.

Duration: Full workshop – 3 hours X 2 days for 2 sessions (there will be a break between the 2 sessions for implementation)

Desired Outcomes:

By the end of the workshop, participants will be able to:

- Explain and demonstrate an understanding of:
 - Basic electricity concepts
 - Circuits, components of a circuit and current electricity
 - Components of a circuit
 - Effects of an electric circuit
 - Resistance and uses of resistors
 - Series and parallel circuits
- Use appropriate and relevant methods to teach basic electricity concepts.
- Conduct practical experiments on assembling electrical circuits.
- Employ various teaching and assessment strategies on the topic Electricity.

Resources:

- Handouts
- Laptop and projector
- Workshop Agenda
- Attendee Notes
- Practical worksheets
- Textbooks and other reference materials
- Video clips from the internet
- Electrical circuit Diagrams
- Cells/batteries and Circuit boards
- Torch bulbs and Switches
- Resistors (steel wool or nichrome wire)
- Copper wires

- Workshop Evaluation Forms

Topic Outline

Understanding the general flow of topics to be covered is an important part of giving a strong presentation. This allows the presenter(s) to lead effective group discussions and speak extemporaneously. The following topics will be covered during the sessions:

Main Topics:

1. Circuits and current electricity
2. Components of a circuit
3. Effects of an electric circuit
4. Resistance
5. Uses of resistors
6. Electric cells as energy systems
7. Series and parallel circuits
8. Safety with electricity

Presentation Outline

SESSION 1

Day 1

Getting Started

Introductions- self, co-facilitator and participants

Explain materials issued to participants

Cover objectives

Topic 1— Circuits and current electricity

Topic 2— Components of a circuit

Topic 3— Effects of an electric circuit

Break

Topic 4— Resistance

Topic 5 – Uses of resistors

Day 2

Reflection of day 1

Topic 6- Factors that affect resistance in a circuit

Topic 7 - Electric cells as energy systems

Break

Topic 8 - Series and parallel circuits

Topic 9- Safety with electricity

Discussions

SESSION 2**Day 1**

Practical tasks and demonstrations

Break

Practical tasks and demonstrations

Discussions

Day 2

Practical tasks and demonstrations

Discussions

Break

Topic- Assessment in Natural Science

Topic- Different teaching strategies

Workshop evaluation

APPENDIX I: LESSON OBSERVATION SHEET

LESSON OBSERVATION SHEET

Name of teacher: _____

School: _____

Grade: _____

Number of Learners: _____

Date: _____

Observer: _____

TOPIC: _____

Item	Yes	No	Comment
The introduction gave learners a clear idea of the topic to be covered in the lesson			
Clear links were made with content that had been learnt previously			
The lesson was clearly structured so that learners knew what was expected of them			
The content was clearly taught			
Learners were given meaningful classroom activities to reinforce the content that had been learnt			
Learners are given the opportunities to share their understanding			
Encourages learners to use appropriate scientific terminology			

Teacher makes use of appropriate teaching aids			
Activities were followed up with clear, helpful feedback from the teacher			
Learners were given meaningful homework activities to reinforce the content that had been learnt			
The conclusion addressed the key content that had been covered in the lesson			

APPENDIX J: INTERVIEW SCHEDULE

Semi-Structured Interview schedule

Thank you for agreeing to participate in this interview. You signed the informed consent form, but I want to remind you that your participation is voluntary and that you can withdraw from this study at any time. This interview should last no more than 25-30 minutes. Interview questions will be asked aloud, this interview will be digitally audiotaped, and I will be taking notes during the interview. You will have an opportunity to review the transcribed interview and make any changes. All transcriptions will be kept confidential, will be coded for confidentiality, and will not be used in any evaluative manner.

The main aim of this study is: To explore how teachers' PCK of electricity concepts influence their teaching.

Interviewee name: _____

1. How long have you been teaching Grade 9 Natural Science?

2. Describe your experience in teaching of Natural Science to this point?

.....

3. What kind of things do you take into consideration in planning an electricity lesson?
(learners' prior knowledge of the topic, learning difficulties with specific science concepts, etc.)

.....

4. What five electricity concepts in your experience, do you consider difficult to teach effectively?

.....

5. What do you think is the reason for you to struggle to teach the above concepts?

.....

6. What knowledge about learner thinking influences your teaching of this topic? Indicate the learners' typical misconception(s) on this topic.

.....

7. How do you address these misconceptions?

.....

8. Do you conduct practical experiments in your teaching of electricity? Please elaborate

.....

9. What effective strategies and methodologies would you use to teach this topic?

.....

10. What are the specific ways for ascertaining learners' understanding or confusion around this topic of electricity?

.....

11. Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge?

.....

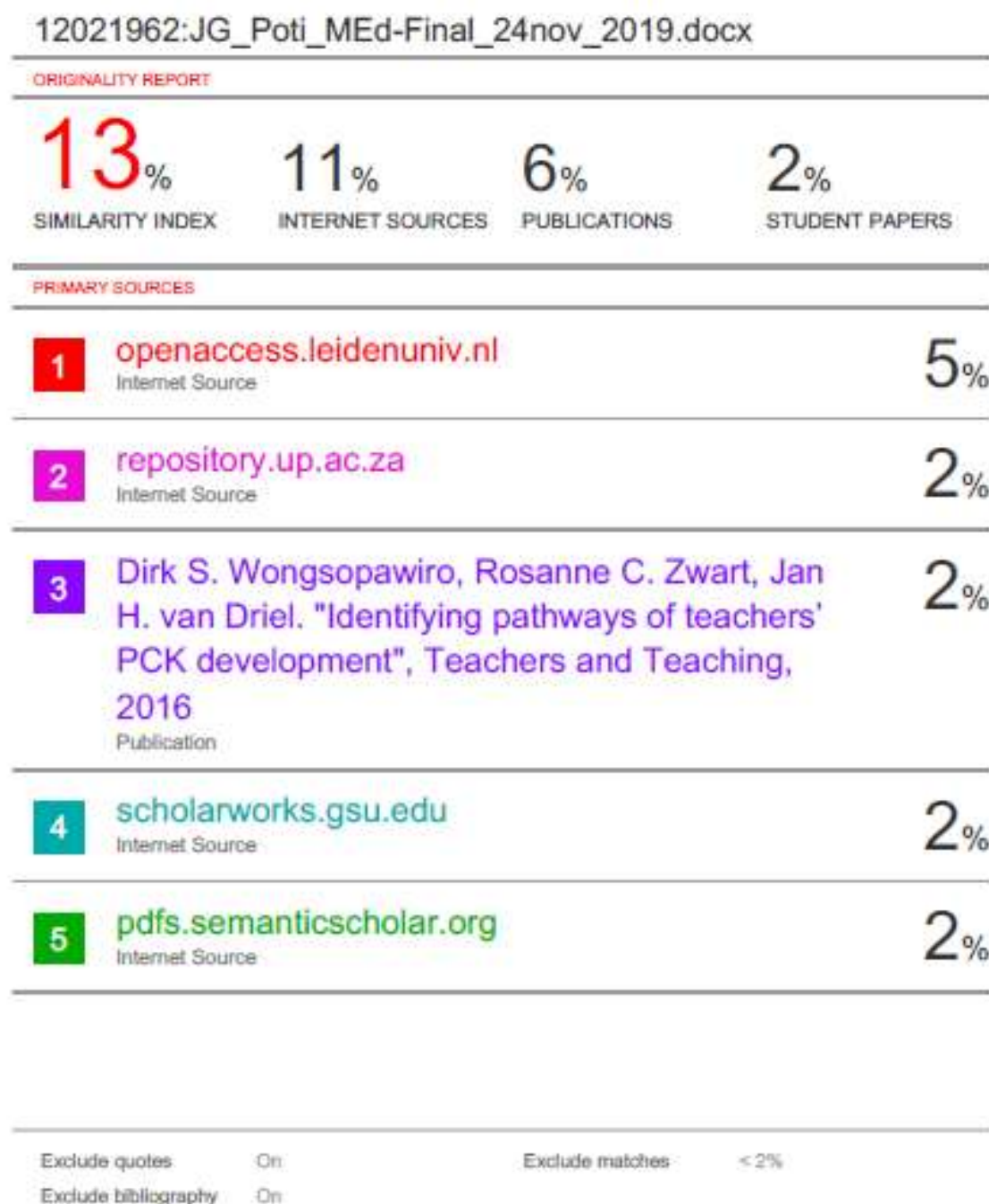
12. Did you achieve some of your professional development needs because of this professional development intervention? Explain

.....



Thank you.

APPENDIX K: TURNITIN REPORT



APPENDIX L: LANGUAGE EDITING REPORT



Office: 0183892451

FACULTY OF EDUCATION

Cell: 0729116600

Date: 24th November, 2019

TO WHOM IT MAY CONCERN

CERTIFICATE OF EDITING

I, **Muchativugwa Liberty Hove**, confirm and certify that I have read and edited the entire dissertation, **Exploring grade 9 Natural Science teachers' PCK in the teaching of Electricity in Moses Kotane Area Office, North West Province**, student number 12021962, submitted in fulfilment of the requirements for the degree **Master of Education in Science Education**.

Joyce Godisamang Poti was supervised by **Prof. Washington T. Dudu** of the North-West University.

I hold a PhD in English Language and Literature in English and am qualified to edit such a thesis for cohesion and coherence. The views expressed herein, however, remain those of the researcher/s.

Yours sincerely

Dr M.L.Hove (PhD, MA, PGDE, PGCE, BA Honours – English)

