UNIVERSITY OF KWAZULU-NATAL

INYUVESI YAKWAZULU-NATALI

EXPLORING TEACHER LEARNING IN A MATHEMATICS CLUSTER AS A PROFESSIONAL LEARNING COMMUNITY IN A DISTRICT

BY

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DECLARATION

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DEDICATION

This thesis is dedicated to the memory of my grandmother Deliwe Filda Ntombana Gunqela Zulu and my grandfather Mshoniseni Ntabayezulu Zulu, I will always remember your teachings. You have been great grandparents to me.

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ABSTRACT

The literature on professional development suggests that teacher clusters serve as an effective platform for teacher learning. This study explored teacher learning in a mathematics cluster as a PLC. It also examined the kinds of mathematics teacher knowledge learn in Siyakhula (pseudonym) and the extent to which this mathematics cluster operates as a PLC. The study is foregrounded on three conceptual frameworks; Birman, Desimone, Porter, and Garet (1999) elements of professional development; Ball, Thames, and Phelps (2008) domains of mathematics teacher knowledge and Stoll, Bolam, McMahon, Wallace and Thomas (2006) features of a professional learning community. The study is located within an interpretive paradigm. The purposive sampling was used to select the case and participants. Multiples forms of evidence were generated through semi-structured interviews, questionnaires, and document analysis.

The findings of the study suggest that mathematics teachers learn formally in the workshops organised by the Department of Education and Non-Governmental Organisations. The findings have shown that teachers learn by interacting with the facilitators, other teachers and doing the tasks that were demonstrated by the facilitators. There was also learning that was taking place outside of the workshop, this learning takes place on WhatsApp group. Regarding the kinds of knowledge, the findings have indicated that the specialised content knowledge, knowledge of content and students/teaching and knowledge of content and curriculum/horizon were learnt in this cluster. The involvement of the three NGO's in the cluster enabled teachers to learn the specialised content knowledge in the workshops. Adhering to PLCs features, the study found that the mathematics cluster displays certain features of a PLC; common vision which is based on learning to improve student learning, distributed leadership among teachers and facilitators, collaboration, individual and group learning. However, regularity of meeting, reflective inquiry and collective responsibility were unclear from the data. For the clusters to function as a PLC the study recommends that all the stakeholders including teachers, DBE and NGOs should come together to promote collaborative learning.

Keywords: *Teacher learning, Professional Development, Professional Learning Communities, Cluster, Mathematics Knowledge*

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LIST OF ACRONYMS

ABET	Adult Basic Education and Training
B.Ed.	Bachelor of Education
BSc	Bachelor of Science
BTEC	Bachelor of Technology
CCK	Common Content Knowledge
CK	Content Knowledge
CASS	Continuous Assessment
CoP	Community of Practice
COVID	Corona Virus Disease 2019
CPD	Continuous Professional Development
DBE	Department of Basic Education
DH	Departmental Heads
DHET	Department of Higher Education and Training
ECD	Early Childhood Education
HCK	Horizon Content Knowledge
ISPFTED	Integrated Strategic Planning Framework for Teacher Education and Development
JIT	Just In Time
KCC	Knowledge of Content and Curriculum
KCT	Knowledge of Content and Teaching
MSSI	Mpumalanga Secondary Schools Initiative
NDIT	National Diploma in Information Technology
NCS	National Curriculum Statement
NGO	Non-Governmental Organisation

PCK	Pedagogical Content Knowledge
PGCE	Post Graduate Certificate in Education
PLCs	Professional Learning Communities
SBA	School Based Assessment
SCK	Specialised Content Knowledge
TLCs	Teacher Learning Communities
UKZN	University of KwaZulu-Natal
USA	United States of America

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CHAPTER ONE

INTRODUCTION AND OVERVIEW OF THE STUDY

1.1 Introduction

South African literature (Jita & Ndlalane, 2009; Jita & Mokhele, 2012; De Clercq & Phiri, 2013; Jita & Mokhele, 2014, Zulu & Bertram 2019) on professional development established that teachers' clusters are becoming useful spaces for teacher learning. In light of these studies, this study explored teacher learning in a cluster of mathematics teachers as a professional learning community in uMgungundlovu district. The chapter is introduced by explaining the background of the study. Followed is an explanation of the rationale for the study, purpose and focus of the study. Subsequently, the research questions of this study and objectives that guide the study are outlined. Additionally, the literature review, conceptual framework and the methodology are briefly presented. I end by giving an outline of chapters of the thesis.

1.2 Background of the Study

This study based on the ongoing exposure of teachers to workshops, cluster meetings and in a various teachers' groups. In a global context, the concept cluster(s) is not new, it has been used in other studies such as Niesz (2007), Lima (2010), Pomoti (2008), Jita and Mokhele (2013); Jita and Mokhele (2014); Jita and Ndlalane (2009); Mitchell and Jonker (2013); Chikoko (2008); Brodie (2019); Jita and Mokhele (2012). The concepts cluster refers to a group of teachers from different schools/departments coming together to share ideas, knowledge, skills, and experiences to develop their classroom practices. Mphahlele (2014) argues that clusters are networks of schools, where teachers work collaboratively with one another. Collaboration of teachers is one of the important features of a PLC. Brodie, (2019) clarified it by saying that: "Collaboration is important not only because teachers learn through collaborating, but it is the key aim of PLCs to produce collectively generated shifts in practice" (p.4). This means that the aim of PLCs in schools or cluster is for teachers to discuss activities, plan together and teach planned lessons. Clusters are well-defined as pillars of mutual support where teachers learn cooperatively (Mphahlele, 2014). Furthermore, clusters can be used as tools to stimulate teacher learning, reflecting in their teaching practice, and sharing common activities in order to enhance pedagogical content knowledge of the subject (Turkey, as cited in Mphahlele, 2014).

In the South African context, the cluster structure generally comprises of one or two subject advisors, cluster coordinator and between eight to ten schools. According to Jita and Ndlalane (2009, p.57) "teacher clusters are being used as a substitute for the traditional approaches to professional development in helping teachers reshape their professional knowledge and change their classroom practices". These initiatives seek to help teachers to develop effective ways of teaching, monitoring of continuous assessment (CASS) and moderation of learners' tasks. South African teachers in secondary or high schools are thus required to attend cluster meetings (formal) because teacher clusters have become an essential aspect in teacher learning in the Department of Education (DoE). The purpose of clusters is for teachers from the different schools, grades, and departments to share their experiences, knowledge, skills and work collaboratively to promote curriculum activities (Mokhele, 2013).

Sometimes teachers' clusters are referred to professional learning communities or communities of practice. Brodie (2019) highlights that PLCs are special communities of practice that encourage collective and collaborative learning. Teachers are working collectively to achieve common goals. This study looked at how mathematics teachers learn in a cluster and identified the type of mathematics knowledge teachers learn**.** Lastly, the study explores the functioning of this cluster as a professional learning community (PLC).

1.3 Rationale

Generally, there is an outcry in South African schools about teaching and learning of mathematics due to the gap in the teacher knowledge. Fink (2006) stated that mathematics teachers enter schools with a gap in their knowledge which hinders their functioning as efficient and effective teachers. This gap seems to be the cause of learners' poor performance in mathematics. Knight (2002) argues that poor performance in matric results in South Africa have been associated with poor teaching of mathematics. Adding to this argument, Pournara, Hodgen and Pillay (2015, cited in Zulu and Bertram, 2019) revealed that many teachers in South Africa lack subject content knowledge. Hence, Jita and Ige (2019) suggest that the most authentic channel of improving learning outcomes is to improve instructional delivery. Jita and Ige (2019) introduced the reflections from the Short Learning Intervention Programme (SLIP) to foster teachers' mathematical knowledge in South

African schools and to set up study groups. This research study thus hopes to contribute to the ongoing debate on how teacher learning occurs, and the kinds of knowledge learnt in a selected cluster.

As a mathematics teacher I have attended some of the professional development initiatives organised nationally for grade 10-12 mathematics teachers, in particular, the aim is to improve the quality of learning and teaching mathematics. Despite all these initiatives, the National Senior Certificate examination results for mathematics do not show any sign of improvement in learner achievement. For example, in the Analysis of KwaZulu-Natal Grade 12 Results for 2019 the mathematics pass rate does not show much improvement: in 2017 it was 41,6% with 50,6% in 2018 but in 2019 it went down to 48,5% (KwaZulu-Natal Department of Basic Education, 2020). These figures seem to attest to the fact that there is no improvement in the mathematics matric results. The KwaZulu-Natal learners' poor performance in mathematics has motivated me to research teacher learning in a mathematics cluster to know how mathematics teachers learn and the type of knowledge learnt in the cluster.

Accumulative research studies on clusters that were led in Mpumalanga province established that "Natural Science and Social Science teachers appear to use the clusters to engage much more deeply with the curriculum frameworks and also to identify and attend to their deficiencies in terms of content knowledge and pedagogical content knowledge" (Jita & Mokhele, 2014, pp.7-8). The results show that teachers' benefit from clusters in various ways through obtaining content knowledge. Additionally, Jita and Mokhele (2014), Mphahlele (2014) stressed that clusters can be an instrument that could be used to 'promote' teacher teamwork, 'reflection' and increasing the learning between teachers. They pointed out that the role of the cluster is to develop teachers by providing necessary support, resources and activities that will help to improve their classroom practice. Furthermore, Mphahlele (2014) revealed that teachers share ideas, knowledge, skills, and classroom practices of teachers which are developed when teachers solve problems collaboratively. I believe that this study will contribute towards enhancing the understanding of teacher learning in clusters as a professional learning community.

Snow-Gerono (2005), Brodie and Borko (2016) and Brodie (2019) claim that clusters can be PLCs in which teachers get an opportunity to learn from each other (collaboratively), their mistakes and discusses their classroom strategies successfully. International literature (McLaughlin & Talbert,

2006; Snow-Gerono 2005; Stoll, Bolam, McMohan, Wallace & Thomas, 2006) and the South Africa policy, ISPFTED identify PLCs, as an effective model of professional development. In line with Snow-Gerono (2005), the Department of Basic Education and the Department of Higher Education and Training (2011) claim that PLCs could enable teachers within the school to learn together and develop each other to improve their classroom practices.

PLCs as school-based professional development have been greatly explored in the context of South Africa. This massive work is evident in Brodie and Borko's (2016) edited book which provides a range of South African studies on PLCs. A recent study on PLCs among high school mathematics teachers who participated in PLCs for 3 to 4 years explored how teachers' professional agency constrained and afforded their participation in PLCs (Brodie, 2019). Interestingly, this study concluded that mathematics teachers were able to see connections between the PLC work and their regular schoolwork and the activities of the PLCs supported their learning for classroom practices. Brodie (2019) further established that members of the PLCs were able to find time to meet with the support of the school leadership and sometimes without it.

The Integrated Strategic Planning Framework for Teacher Education and Development (ISPFTED) 2011-2025 was introduced in South Africa with the intention of improving teacher education and professional development opportunities for teachers in their places of work. The ISPFTED supports teachers to form professional learning communities where teachers and subject advisors share knowledge and resources. This study therefore sought to find out how mathematics teachers learn in a cluster and understanding the kinds of mathematics knowledge learned in cluster. Many South African studies (Cereseto, 2015; Brodie & Borko 2016, Brodie 2019) on PLCs seem to focus on PLCs which include university academics and NGOs.

The international literature (Stoll & Louis, 2008; Stoll, Bolam, McMohan, Wallance & Thomas, 2006; Owen, 2014) has stressed that not all groups of teachers are regarded as PLCs, but PLCs have certain features or characteristics. In the light of this statement the study also examined the extent to which the mathematics cluster displays the features of PLCs. In addition, this study assists in contributing and increasing the understanding of teacher learning in clusters as professional learning communities (PLCs).

1.4 The Purpose and Focus of the Study

This study explored teacher learning in a mathematics cluster as a PLC. It also examined the kinds of mathematics teachers learn in Siyakhula (pseudonym) and the extent to which this mathematics cluster operates as PLCs. The research focuses on grade 10 - 12 mathematics teachers in a selected cluster. In the South African context, subject clusters operate outside of the school context. The mathematics teachers of this cluster came from 12 high schools in one of the circuits of uMgungundlovu district in Kwa-Zulu Natal province.

1.5 Problem Statement

South African studies (Jita & Mokhele 2014; Mphahlele 2014 & Makhaye 2015) on professional development have established that teacher clusters could operate as PLCs. In relation to PLCs, the South African policy (ISPFTED) stipulates that PLCs are important to strengthen teacher professionalism and to promote collective participation in professional activities for professional development. However, it is still unclear about the extent to which existing clusters operate as PLCs. The study is focusing on the mathematics cluster as a PLC because teaching and learning of mathematics in South African schools is still a challenge (Chauraya, 2013). This is evident from the Department of Basic Education document, 2020 (Mathematics Results Analyses) of grade 12 learners that the quality of mathematics results has been deteriorating for the past three years, this had been of great concern for teachers and other educational stakeholders. Therefore, is important for this study to find out how mathematics teachers learn in a cluster and the type of mathematics knowledge they learn.

1.6 Research Questions

The three research questions were formulated based on the purpose of this study:

1. How do teachers learn in a mathematics cluster?

2. What type of mathematics knowledge do teachers learn in a mathematics cluster?

3. To what extent does the mathematics cluster adhere to the features of a professional learning community?

1.7 Objectives of the Study

Objectives of the study are informed by the research questions above and are provided below:

1. To examine how teachers, learn in a selected mathematics cluster.
2. To describe the kinds of mathematics knowledge they learnt in a mathematics cluster.
3. To explore the extent to which the mathematics cluster adheres to the features of a professional learning community.

1.8 Preliminary Literature Review and Conceptual Framework

This section briefly defines the conceptual frameworks of this study. The concepts relating to this study include professional development, teacher learning, professional learning communities and clusters.

According to Desimone (2011) professional development (PD) refers to a range of specific training, official education and advanced professional learning that is projected to aid educational managers, as well as teachers to improve their skills, information, proficiency, and efficiency. Professional development normally takes place in different spaces such as workshops, school and cluster meetings and even in classrooms with mentors. These are the places where teachers can get help to overcome some difficulties that they experience in their teaching (Brodie & Borko, 2016).

Professional development is linked to teacher learning in that professional development could have a positive impact on teacher learning (Borko, 2004). Many empirical studies (Kelly, 2006, Kwakman 2003, Borko, 2004) indicate that teacher learning takes place in different aspects of teachers' practices. Kelly (2006) thus defines teacher learning from two perspectives: cognitive and socio-cultural perspectives. In the cognitive approach, teacher learning refers to the "process by which teachers move towards expertise" (Kelly, 2006, p.506). In this approach knowledge, skills and understanding are acquired in one setting and then teachers are able to use these skills, knowledge and understanding somewhere else. This entails that teachers learn in one space. In a socio-cultural approach, "teacher learning is the movement of teachers from a peripheral (novice) to full (expert) participation in the specific working practices and their associated ways of knowing and thinking which defines particular school circumstances" (in Kelly, 2006, p.507). According to Lave and Wenger (1991) this entails that knowledge is disseminated across teachers, artefacts, and learners, is not owned by an individual, knowledge is learned by participation and learning happens

in a particular context.

The literature revealed that teachers' learning occurs when teachers' work cooperatively, discuss issues of curriculum, new knowledge, skills and challenges of teaching and learning (Mphahlele, 2014). Moreover, teacher learning is well-defined as a process whereby teachers are implicated in all activities that change knowledge (Bakkenes, Vermut & Wubbels, 2010). Korthagen (2017) declares that teachers' behavior is directed by three influences: cognitive, affective and motivational dimensions. He further highlights that beliefs and the right insight would change teacher's behaviour because they continuously made few planned decisions while in class teaching and their behaviour is influenced by thinking. Korthagen (2017) explained that teaching is a profession whereby feeling and motivation play an important role.

DuFour, DuFour and Eaker (2008) acknowledge the importance of professional learning communities as model of professional development. Jansen, Cummock and Conner (2010) defined a professional learning community as a collection of motivated people who share ideas, knowledge, learning, vision, and new approaches to teaching that will improve learners' achievement. Stoll, Bolam, McMahon, Wallace, and Thomas (2006) mentioned that PLCs are formed by a group of people who learn collaboratively, share information, and critically reflect on their practice. Correspondingly, Louis (2002) states that in professional learning communities people collectively share and critically interrogative their teaching practice. The aim is to enhance teacher's professional knowledge for the benefit of students. Mason (2003) adds that PLCs are important structures that focus on the mutual learning of teachers where values and beliefs are shared with the aim of improving students' results. In addition, Brodie (2019) stated that school leadership needs to provide teachers with the space and time for the professional learning community be effective.

Furthermore, "professional learning communities encourage transition from a tradition of isolation to a culture of collaboration" (DuFour, DuFour & Eaker, 2008. p.27). DuFour, DuFour and Eaker (2008) also describe PLCs as teachers who are dedicated to working together collaboratively with the intention of students attaining good results. These authors claim that PLCs function under some certain assumptions that the crucial purpose is for professional development of teachers and improved learning of students. DuFour, DuFour and Eaker (2008, pp.15-17) pointed out the:

> six features of effective PLCs: shared mission, vision, values and goals focusing on learning, a collaborative culture with a focus on learning, collective inquiry into best practice and current

reality, action orientation: learning by doing, a commitment to continuous improvement, and results oriented.

There are scholars who defined learning communities as clusters of teachers working collaboratively to adjust and improve teachers practice meeting learner's needs, which improves a collaborative working culture for teachers and is for the ultimate benefit of students (Stoll et al., 2006; Hord, 2009). A cluster in this study (as also highlighted by Chikoko, 2007) is the group of teachers from various schools within a circuit who come together to talk about their teaching experiences for the sake of their development. Furthermore, clusters are networks of schools, where a particular group of teachers shares common ideas. In addition, Makaye (2015) refers to clusters, as communities of practice and networks, as systems of collaboration that are related amongst schools and teachers that embolden learning. According to Jita and Mokhele (2014), clusters represent a group of teachers from different schools, grades, and departments within a similar geographical area called a circuit.

Krauss, Baumert, and Blum (2008) look at teacher knowledge as a vital element in the mathematics classrooms. There are "three sub-dimensions that were identified specifically important to mathematics teaching and used these sub-dimensions to guide tests constructions namely, mathematical tasks, knowledge of student misconceptions and difficulties and knowledge of mathematics-specific instructional strategies" (Krauss et al., 2008, p.875). The first sub-dimensions are mathematical task, they mentioned that tasks play a significant role in the mathematics teaching. Teachers' knowledge is measured by testing teacher's capability, and they are expected to produce multiple solutions. Secondly, teachers should first seek prior knowledge and use students' conceptions. Krauss, Baumert, and Blum (2008) pointed out that teachers should be aware of the misconceptions and challenges faced by students. Lastly, the construction of student knowledge needs to be supported and guided by teachers.

Holmes (2012, p.55) categorised knowledge into two namely, content knowledge and content knowledge for teaching. He mentioned that teachers must display a good understanding of the mathematics content which includes mathematics procedures, understanding of the concepts of mathematics, algorithms and define mathematics relationships. Teachers are expected to solve non-routine problems and to be able to make mathematical connections (Holmes, 2012). Teachers must teach the meaning behind the symbols and in order to do so a teacher must understand both procedurally and conceptually (Holmes, 2012, p.60). He declares that teachers must make connections with the real-world objects and pictures.

Teacher content knowledge is divided into three main dimensions: content knowledge, pedagogical content knowledge and curricular knowledge (Shulman, 1986 as cited in Holmes, 2012, p.64). All these elements are explained in Chapter Three. Ball, Thames, and Phelps (2008) proclaims that teachers should have an understanding of the mathematics content, mathematics language used and have skills for teaching mathematics. The study aims at understanding teacher knowledge, teaching and the learning of students. The focus is more on the teaching of mathematics. Ball, Thames, and Phelps (2008, p.399) categories mathematics knowledge into five elements such as "common content knowledge, specialised content knowledge, knowledge of content and students, knowledge of content and teaching, knowledge of content and curriculum horizon" These elements are built on four domains of teacher knowledge by Shulman (1987). Criticisms of Shulman's teacher knowledge include the:

> problem of identifying mathematical knowledge for teaching, little attention was devotedto examining content and its role in instruction that Shulman dubbed this the missing paradigm in research on teaching and teacher knowledge, lack of definition of key terms, pedagogical content knowledge is not clearly distinguished from other forms of teacher knowledge (Ball, et al., 2008, p.390).

These authors felt that a different conceptualization is necessary for subject matter knowledge in mathematics. Ernest (1989) clarifies this:

> The teacher's knowledge of mathematics is a complex conceptual structure which is characterized by a number of factors, including its extent and depth; its structure and unifying concepts; knowledge of procedures and strategies; links with other subjects; knowledge about mathematics as a whole and its history (p.16).

Ball et al. (2008) argues that teachers need mathematical knowledge and skills for their teaching to be effective. The study further looks at the type of mathematics knowledge learnt in a cluster.

This study used Birman, Desimone, Porter, and Garet's (1999) elements of designing professional development and Ball, Thames, and Phelps' (2008) domains of mathematics knowledge and features for PLCs as conceptual frameworks for this study (Stoll, Bolam, McMohan, Wallance &Thomas, 2006). Birman, et al. (1999, p.29) identifies six elements namely, "form, duration, participation, content focus, active learning, and coherence". The elements of Birman, et al. (1999) can be used when exploring studies in relation to teacher development, with a specific focus on mathematics and science. These six elements of designing professional development provided an

insight on how mathematics teachers learn in a cluster. The elements are further categorised into two groups. The first three groups consist of elements that looks at “structural features that set the context for professional development” (Birman, et al., 1999, p.29). The last three elements are meant to "identify core features that characterise the processes that occur during a professional development experience" (p.29). These elements helped to understand how mathematics teachers learn in a cluster.

Additionally, Ball, Thames, and Phelps (2008) categorise domains of mathematics knowledge namely: “Common Content Knowledge (CCK), Specialised Content Knowledge (SCK), Knowledge of Content and Students (KCS), Knowledge of Content and Teaching (KCT), Horizon Content Knowledge (HCK) and Knowledge of Content and Curriculum (KCC)” (p.403). By using Ball, Thames and Phelps assisted in identifying the type of mathematics knowledge teachers learn in a selected cluster. Base on the third research question of this study the features of PLCs were used to determine the extent at which the mathematics cluster functions as a professional learning community (PLC). The key features of the PLCs identified by Stoll, Bolam, McMohan, Wallance and Thomas (2006) are mutual trust and respect; support challenge and constructive critique; share vison and a focus on learning for all learners; collaborative and reflective enquiry; inclusive membership; leadership, collective responsibility for student learning, coherent, responsive change in practice, regularity, and systematic, rigorous enquiry into practice.

1.9 Methodological Approach

The study adopted a qualitative case study design. Drawing from Creswell (2012), the qualitative research approach in this study is grounded in discovering and understanding a group of mathematics teachers’ experiences. The study is located within an interpretive paradigm since, this paradigm is based on the interpretation of the world from the participants’ perspective (Cohen, Manion & Morrison, 2011). Furthermore, Cohen et al. (2011) contends that adopting the interpretive paradigm in this study assists a researcher in understanding and describing the meaning of social action of teachers in the clusters. Thomas (2011) stated that a case study is a detailed study that focuses on a specific phenomenon that is viewed from numerous perspectives. This is supported by Rule and John (2011) who asserted that a case may be an individual event, an organisation, or a community. This research sought to obtain rich and thick in-depth data by looking at one cluster of mathematics teachers. The mathematics cluster consisting of 21 teachers from 12 high schools. The data was collected through unstructured observation, semi-structured

interviews, and document analysis. Purposive sampling was used to select participants consisting of a cluster leader, lead teacher and the subject advisor. All the individuals who were selected for interviews were purposefully chosen due to their position, experience, and length of time they had been members of the cluster. The data generation method used is semi-structured interviews. Furthermore, documents were analysed including attendance registers, cluster minutes, communiques used by the subject adviser and worksheets. A detailed account on the methodology of this study is presented in Chapter Three.

1.10 Dissertation Overview

This research study consists of five chapters.

Chapter One presents the general overview of the study, including an introduction and gives the background and the rationale of the study. The focus and purpose, the three research questions and objectives of the study are also described in this chapter. A preliminary review of literature and conceptual frameworks underpinning the study are provided. The chapter also presented a brief discussion of the methodology of this study.

Chapter Two presents the literature review on teacher learning, professional development, professional learning communities and clusters. The chapter explains the conceptual frameworks that were used as a lens through which data was analysed. Birman, et al. (1999) elements of designing professional development works for improving teaching practice. Ball, Thames, and Phelps' (2008) domains of mathematics knowledge, and Stoll, Bolam, McMohan, Wallance and Thomas' (2006) feature of PLCs used as lens for this study.

Chapter Three presents the research design and methodology used to carry out this study. The instrument used to collect data namely, semi-structured interviews, cluster observation and documents analysis. The sampling method, issues of trustworthiness and ethics was also outlined.

Chapter Four presents the analysis of data collected. Themes were used to present data and, I used conceptual frameworks to analyse data.

Chapter Five, the last chapter, presents the discussion of findings according to the three research questions for the study. The chapter ends with the conclusions and recommendations for future areas of research.

1.11 Conclusion

This chapter outlined the introduction and the overview of the study. This chapter discussed the background, rationale, focus and purpose of the study. In addition, the research questions and objectives of the study were highlighted. The preliminary literature review, conceptual frameworks and the methodology of the study were presented. The following chapter presents the literature review and the conceptual frameworks of the study.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter reviews the relevant literature on teacher learning in teachers' clusters and professional learning communities. The first section of this chapter attempts to explain the concept teacher learning and activities that contribute to teacher leaning. Secondly, it explains the meaning of professional development and the features of professional development. In the third section of the chapter, professional learning communities (PLCs) were discussed. The fifth section discusses teachers' clusters. Finally, the last section discusses the three conceptual frameworks that were adopted in this study; Birman, Desimone, Porter, and Garet's (1999) elements of professional development; Ball, Thames, and Phelps (2008) domains of mathematical knowledge and Stoll, Bolam, McMohan, Wallace and Thomas' (2006) features of PLCs.

2.2 Teacher Learning

Teacher learning happens in various aspects of practice for example in classrooms, school communities and in workshops. In addition, teacher learning can happen inside or outside the school premises. It can also take place individually with teachers reading books, learning in their classrooms, outside the school when talking to an unruly child and reflecting on their teaching practice (Borko, 2004). In addition, "teacher learning can be collaboratively where teachers meet in a workshop and plan for the term" (Borko, 2004, p.4). This is in line with the study conducted in the Free State which indicated that teachers in the workshops learn collaboratively where they plan lessons together, learn by observing other teachers conducting the experiments and groups presentations (Jita & Ige, 2019). This means that teachers in workshops learn together by sharing knowledge and classroom practices.

Moreover, Korthagen, claimed that teacher learning is frequently unplanned, and the behavior is guided by many processes happening without conscious awareness and is connected to teachers' feeling and emotions. He further explained that teacher learning is multi-dimensional, which means that the cognitive, affective, and motivational aspects are linked or fixed in a social context. Teacher learning is intertwined with theory, practice, and person. Additionally, Korthagen asserts that teacher learning happens at different places. This denotes that teacher learning can be formal or informal and it is an on-going process. Teachers learn formally in their practice, and they also

learn informally outside of the classroom. This is further supported by Forte and Flores (2014) when they say that teachers learn not only formal, planned and structured elements but also learn more informal, unplanned, contextualized and collaborative dimensions of teacher learning.Avalos (2010, p.10) asserts that "professional teacher learning is a complex process, which requires cognitive and emotional involvement of teachers individually and collectively, thecapacity and willingness to examine where each one stands in terms of convictions and beliefs andthe perusal and enactment of appropriate alternatives for improvement or change". This entails that teacher learning involves mental reasoning, behavior of teachers and improved learners' performance or achievement.

Kelly (2006) defined teacher learning as a cognitive and socio-cultural approach. Cognitivism is described as a theory where "individuals acquire skills, knowledge and understanding in one setting, often specifically designed for that purpose, and are subsequently able to use these skills, knowledge and understanding elsewhere and the knowledge reside in the individual's mind" (p.506). This definition shows that knowledge is learnt in one space and then transferred to a new space. This theory states that for novice teachers to become an expert, they need to learn a defined 'body of knowledge' which constitutes professional expertise, and then apply this in their classroom practices. Thus, professional development workshops put this theory into practice and learning is understood as an individual endeavour.

Teacher learning in the socio-cultural approach is defined as a collaborative endeavour, a 'knowing-in-practice' which is dispersed across teachers, students and resources (Kelly, 2006). According to Kelly (2006), in the socio-cultural theory, teachers develop skills, knowledge an understanding in the workplace, through participation in the practice and the learning is situated in the workplace. Moreover, Lave and Wenger (1991 as cited, in Kelly, 2006, p. 507) proclaims that "teacher learning is the movement of teachers from peripheral (novice) to full (expert) participation in the specific working practices and their associated ways of knowing and thinking which define particular school circumstances". Participation in the working practices involves teachers work collaboratively: planning together, sharing the activities, helping each other that improve their teaching practice. In addition, socio-cultural theory focuses on "knowledge-in-

practice" where knowledge is developed by teachers through experience, this knowledge is tacit because it not easily articulated (p.506).

The international study conducted by Meirink, Meijer, Verloop & Bergen (2009) on teacher learning in the workplace and examination of teacher learning activities. The study revealed that teachers learn more on activities that are self-initiated. They classify learning activities into five categories which includes "learn by doing, experimentation, reflection on experience, learning from others without interaction and learning from others with interaction" (p.210). They concluded that colleagues play a big role in teacher learning because other teachers learn by observing their colleagues and discovering alternatives teaching methods. This implies that teachers learn by observing other teachers teaching and reflecting on teaching experiences.

Many empirical studies indicate that teacher learning takes place in different ways. Sfard (1998) identified the acquisition metaphor and participation metaphor as one of those that describes learning. The participation metaphor is defined as "learning as participation and subjects needed to be conceived in order to become a member of certain community and have the ability to communicate in the language of that community and acts according to that particular norms" (Sfard, 1998, p.6). Therefore, the focus is on inward knowledge where knowledge is internalized and individualized. Additionally, "the acquisition metaphor designates learning as an act of gaining knowledge and an accumulation of concepts" (p.6). Therefore, the focus is on inward knowledge where knowledge is internalized and individualized. "The participation metaphor" focuses on 'knowing' as an activity and learning as participation in a certain activity rather than accumulating knowledge.

Both Kelly (2006) and Sfard (1998) describe individual learning as acquiring or gaining knowledge and concept accumulation. It is a cognitive process, where collaborative learning is more like a socio-cultural approach that involves practical activities that seek to change the conception of knowledge (Bakkenes, Vermut & Wubbel, 2006). Additionally, Dufour (2004) mentioned that teacher learning occurs through peer observation, collaboration, individual inquiry, experiential learning, conferences, workshops, and graduate courses. On the other hand, teacher learning from a situative perspective is defined as "a process of increasing participation in the practice of teaching, and through this participation, a process of becoming knowledgeable in and about teaching" (Adler, 2000, p.37). This quote suggest that teacher learning happens when

teachers from the same school or clusters learn from each other formally or informally with the aim of improving learners' performance.

Kwakman (2003) proclaims that reflecting is an important activity because teachers should reflect on their work of "supervising student teachers and receiving coaching guidance (p.155)". Supervising novice teachers is therefore an activity that could contribute to the professional development of a student teacher. He stated that teachers should coach each other and received feedback from their colleagues. This denotes that within the institution an individual teacher is responsible to monitor each other's work and be able to write/give feedback. Lastly, collaborating, teachers are expected to help one another and give help where necessary (Kwakman, 2003). Teachers should tell stories about their teaching practice and share learning materials. New ideas, skills and knowledge are shared amongst colleagues (Kwakman, 2003). Moreover, teachers should share "instructional issues, ideas about education and ideas about pupils counselling" (Kwakman, 2003, p.155). In a collaborative activity, teachers are expected to work as a team, prepare lessons together and improve classroom practice.

2.3 Professional Development

The definition of the professional development is contested. Day (1999) defines professional development as how teachers and other members of the teaching profession improve and broaden their knowledge and skills to develop the personal qualities needed in their professional lives. According to UNESCO's International Institute for Education Planning (2003) professional development is more than a career development, it involves both formal and informal experiences. Formal experience includes workshops, conferences, university courses and informal experiences include reading academic and professional related publications. Similarly, of formal and informal professional development experiences, Knapp (2003) highlights that professional development comprises of structured experiences such as workshops and unstructured experiences occur when teachers are discussing their work. Furthermore, Knapp (2003) stated that professional development are the activities that are intended to bring about changes in teachers' classroom practices.

According to Evans (2014, p.188) "professional development is the process whereby people's professionalism may be considered to be enhanced, with a degree of performance that exceeds transitoriness". This implies that teacher professionalism needs to be developed and improve the way teachers' think, content knowledge and learning of students also need to be improved. He

further mentioned that professional development may possibly take place in any formal or informal context. Professional development frequently happens step-by-step like a chain "whereby one change dimension leads to another" (Evans, 2014, p.194). This denotes that professional development enhances teachers' knowledge and improves the learning of students.

Desimone (2011) argues that professional development (PD) can be used with regard to a range of specific training, official education and advanced professional learning that is projected to aid educational managers, as well as teachers to improve their professional knowledge, skills, competence and effectiveness. In addition, Desimone (2011, p.68) contends that teacher professional development should "increase teacher knowledge and instruction in ways that translate into enhanced student achievement". In addition, Guskey (2002) and Desimone (2011) argue that professional development requires time for it to be effective. Time set aside is an essential part of the combined collegiate discussion; it allows collaborative activities which include planning, co-teaching, modelling, and reflecting, allowing teachers to develop professionally.

Desimone (2002, p.30) further explains "successful professional development as:

- Professional development increases teachers' knowledge and skills, changes their attitudes and beliefs, or both.
- Teachers use their new knowledge, skills, attitudes, and beliefs to improve the content of their instruction, their approach to pedagogy or both.
- The instructional changes that teachers introduce to the classroom boost their students' learning.
- Teachers experiences professional development changes the way they attempt problems in classrooms and changes student achievement".

Easton (2008) discussed that professional development in schools should take place mostly in the morning and afternoon. He mentioned that coaching, mentoring, and examining teachers' practice must happen within the school in different times. Easton (2008) introduced the beneficial activities embedded in teachers' work such as: "action research, assessment design, book studies, critical friends' groups and lesson study" (p.758). These activities were the powerful weapon to addresses content and improve teachers' practice. He further stated that professional development of teachers

should be evaluated including the behaviour of teachers and changes of learners' behaviour. Easton (2008) stated that teachers must be assessed the way they work after professional development has been conducted. He believed that if teachers changed their behaviour that would influence the behaviour of learners. Learners would behave differently in the classroom and even at school.

Calvert (2016) conducted a study based on the power of teacher agency. The study focused on how schools could improve teacher agency for learners to learn well. Calvert (2016, p.52) defined teacher agency in the context of professional development "as the capacity of teachers to act purposefully and constructively to direct their professional growth and contribute to the growth of their colleagues". Calvert (2016) states that teachers should own their agency and be responsible for learning. However, the study findings revealed that many teachers have not been engaged in professional development and the majority of schools failed to provide teachers with learning experiences. Calvert (2016) pointed out that teachers do not avail themselves for professional development. He believed that "to transform professional learning so that it really supports educator learning, education leaders will need to pay greater attention to the importance of teacher agency" Calvert (2016) (p.52). He suggested seven steps that school leaders and district can do to improve education in their professional learning (p.53).

- Make all professional learning decisions only in serious consultation with teachers and principals. Ensure at least a five percent teacher representation on school and district teams that are responsible for every stage of decision making, from planning and data analysis to design, implementation, and evaluation.
- Rethink organisation of the school day so that educators have time to meet regularly to collaborate with colleagues to improve teaching and learning.
- Involve and support teachers in analysing data and identifying teaching and learning challenges.
- Establish learning communities where educators solve problems of practice and share responsibility for colleagues and students' success.
- Give teachers choices regarding their professional learning, including with whom they work and where they focus their learning.
- Ensure that professional learning is for the purpose of continuous growth, not evaluation.

- Resist the temptation to scale up or mandate a particular form of professional learning without thoroughly examining the context in which it will be implemented. Understand that teachers must want to improve their practice and see how the learning opportunity will help them do so.

These steps would be important for improving teacher education and developing their classroom practices. Calvert (2016) explained that teachers should be part of all decision making in professional learning. Teachers must take control of the professional development they need. In addition, schools and districts must provide support to teachers.

Zeichner (2003), conducted a study on professional development for teacher research programs for P-12 educators based at school level. The study revealed that the training model has become the most common model that improved teachers teaching practices. Likewise, Kennedy (2005) refers professional development as a continuing professional development (CPD) where teachers continuously improve their knowledge, skills, attitudes and behaviours. In the same vein, Mokhele (2013) viewed CPD programmes as "systematic efforts to change the practices of teachers in the classroom, to change their attitudes and beliefs, and to change the learning outcomes of students" (p.76). Additionally, Bolam (2000) asserts that professional development is an important part of improving the performances of the school. This indicates that the intensive professional development can enhance teachers' understanding, expertise, reflection and their attitudes to teaching is changed.

Kennedy (2005) who has introduced nine models that support teachers' continuing professional development in schools namely, "training, mentoring/coaching, community of practice, cascade, award bearing, standards-based, action research, deficit and transformative". These models are useful to teachers in professional development. Kennedy (2005) mentioned that a training model is a universal model that provide teachers with the necessary skills and competence established. The model also supports "the skills-based, technocratic view of teaching whereby continuing professional development (CPD) provides teachers with the opportunity to update their skills in order to be able to demonstrate their competence" (Kennedy, 2005, p.237). Generally, an 'expert' conveyed workshop agenda to the subject teacher and teachers become passive. These training workshops are meant to shape teaching, learning and improve learners' achievement. This

corresponds with Hoban (2002) who defined training model as way of familiarizing with new knowledge.

In the South African context, the training model together with cascade model were mostly used in 1997, when the Outcome Based Education was introduced to teachers. Kennedy (2005) highlights the cascade model takes place when teachers attend a training workshop and then the information is distributed. The cascade model is commonly used when the resources are not enough. The learning takes place at school level and generally have formal feedback. This model is regulated externally by the Department of Basic Education (DBE). The limitation of this model is that if the teacher who attended does not distribute the information as anticipated or does not give details on the learning principles from the 'training workshop' (Kennedy, 2005, p.240).

Coaching and mentoring of novice and newly appointed teachers are important in professional development. Mentoring/coaching is defined as a 'peer coaching' and intended to give professional support to novice teachers (Kennedy, 2005, p.244). According to Kennedy (2005) coaching/mentoring occurs where an experienced teacher has a close relationship with the novice teacher, it happens between two teachers. The purpose for the coaching/mentoring model "involves mutually supportive and challenging, or hierarchical and assessment driven, the quality of interpersonal relationship is crucial (Kennedy, 2005). In a school or classroom context, coaching/mentoring can happen through sharing ideas, views, and dialogue with colleagues. In the South African schools, the aforementioned professional development activities are usually initiated and controlled by the Departmental Heads (DHs). In line with Kennedy (2005), it is thus believed that novice teacher acquired new skills, values and knowledge during the process of coaching and mentoring.

Another model of professional development is a community of practice. According to Kennedy (2005) a community of practice (CoP) involves people that are more than two and happens where the collective members of a community shape the individual's understanding. Additionally, a community of practice is formed by a group of teachers who are driven by the goal of supporting each other. Furthermore, Wenger (1998) as cited in Kennedy (2005, p.244) discussed that learning within community of practice "includes three essential processes such as:

- Evolving forms of mutual engagement;
- Understanding and turning [their] enterprise;

- Developing [their] repertoire, styles, and discourse.

In the community of practice teachers learn collaboratively with the intention of developing one another. The new knowledge and skills is generated by the effectiveness of the connection between teachers in the community of practice (Kennedy, 2005). Wenger (1998) stated that the knowledge of individuals and experiences increased sufficiently by means of a cooperative endeavour.

Continuing professional development (CPD) could be enhanced through an award bearing model. According to Kennedy (2005), an "award bearing model of continuing professional development (CPD) is one that relies on the completion of award-bearing programmes of study-usually, but not exclusively, validated by universities" (p.238). This university validation was regarded as an exercise of funding bodies' but then, this exercise of award-bearing/validation did not focus on the classroom practice and instead focused on the academic work of the universities. Thus, this model emphasises the completion of award-bearing programmes of study. The learning is formal, and it is a long-term process. In addition, facilitators/ lectures control the professional development, and the emphasis is on professional action.

Teachers should show that they are professionally competent to do particular activities. The standards-based model requires certain standards to be met for professional development. Kennedy (2005) explains that the standard-based model focuses on the competence of individual teachers and resultant rewards at the expense of collaborative and collegiate learning. The model places the emphasis on the 'professional actions' (Kennedy, 2005, p.240). In the standards-based model teachers are encouraged to take responsibility for their own professional learning and shouldassess their own teaching capacity (Kennedy, 2005). However, this model is not well known in South Africa. Kennedy (2005) also emphasised that teachers' performance should be evaluated and managed. Evaluation of teachers could show their weakness that can be addressed through the deficit model of CPD. Kennedy (2005) defines the deficit model as a "professional development that can be designed specifically to address a perceived deficit in teacher performance" (p.239). This model assists the individual who has some weaknesses.

Action research is another model of professional developmental which is transformative. A transformative model of CPD "involves the combination of a number of processes, conditions and practices that support the transformative agenda" (Kennedy, 2005, p.246). Kennedy (2005) claims that in action research model, the researcher studies the social situation whereby the participants

are the researchers themselves with the purpose of advancing action research quality. Burbank and Kauchak (2003) established that many researchers of communities of practice engaged in an action research model and in practice, it has good outcomes. Kennedy (2005, p.245) contends that "collaborative action research provides an alternative to the passive role imposed on teachers in traditional models of professional development" The action research model allows teachers to question their practice. Kennedy (2005) stated that professional development is initiated by the researcher and commonly happens in the classroom. In this model, teachers within the practice develop professional judgement (Kennedy, 2005).

Mokhele (2013) asserts that continuing professional development (CPD) is the most effective approach that contributes more to improving teachers' instructional and classroom practice. Additionally, CPD of teachers is the main key aspect in making sure that education reforms are effective. The aim of education reform is to improve teacher performances in their practices and the learning of students; therefore, teachers are expected to advance their learning and teaching skills by engaging in professional development activities (Harwood & Clarke, 2006). This is also supported by Borko (2004) who reveals the evidence that CPD programmes enhance teacher knowledge, and their instructional practice is also improved. These practices include:

> A focus content and how student learn the content, in- depth, active learning opportunities, link to high standards, opportunity for teacher to engage in leadership roles, extended duration and the collective participation of groups of teachers from the same school, grade or department (Desimone, 2002, p. 86)

Avalos (2011) claims that professional development is more about teacher learning and the activities that improve individuals' skills and knowledge however, knowledge is transformed into practice for their students benefit and growth. This is aligned with Avalos (2010) where professional development is defined as the learning which transforms teacher knowledge into practice and benefits the growth of the students. Similarly, Hammond, Hyler and Gardener (2017, p.5), described effective professional development, "as structured professional learning that results in changes of teacher practices and improvements in students learning outcomes". Hammond et.al (2017) indicates that professional development mostly happens in an organised learning environment such as workshops planned by the Department of Education, furthermore, students

results also changed and improved the teachers' practices. Hammond et.al (2017, p.5) suggest seven features for effective professional development which are:

- Content focused: focus is on strategies of teaching with relation to specific curriculum content and supports teacher learning within teachers' classroom contexts.
- Incorporates active learning and engages teachers directly in designing and trying out teaching strategies, providing them with the opportunity to engage in the same style of learning they are designing for their students.
- Supports collaboration: Professional development creates a space for teachers to share ideas and collaborate in their learning. By working collaboratively, teachers can create communities that positively change the culture and instruction of their entire grade level, department, school and or district.
- Use models of effective practice: curricular models and modeling of instruction provides teachers with a clear vision of what best practices look like. Teachers may viewmodels that include lesson plans, unit plans, samples of students' work, observation of peer teachers and video or written cases of teaching.
- Provides coaching and expert support which involves the sharing of expertise about content and evidence-based practices, focused directly on teachers' individual needs.
- Offer feedback and reflection: high-quality professional learning frequently provides built-in time for teachers to think about, receive input on and make changes to their practice by facilitating reflection and soliciting feedback.
- Sustained duration: effective professional development provides teachers with adequate time to learn, practice, implement and reflect upon new strategies that facilitates changes in their practice.

Hammond et al. (2017) highlights that for effective professional development to take place, teachers must support each other, work collaboratively so as to share ideas, skills, information, knowledge and create communities of learning. The use of teaching models, observing peer teachers and giving feedback frequently is encouraged. In agreement with these authors, Evans (2014) defined professional development as a "process whereby peoples' professionalism may be considered to be enhanced by a degree of performance that exceeds transitoriness" (p.188). Moreover, Evans (2014) pointed out that teachers' professionalism needs to be observed before

addressing issues related to professional development. A study conducted by Pitsoe and Maila (2012) revealed that teachers' professional development is vital, as teachers', teaching methods change, and they get a chance to explore new roles and new instructional techniques are developed. They further explained that the reason for teachers to be developed professionally is toassist with new understanding of teaching methods and learning.

Furthermore, Guskey (2002) argues that teachers' beliefs attract them to professional development with the aim of expanding their knowledge and skills as well as their growth. He further explained that "professional development activities are frequently designed to initiate change in teachers' attitudes, beliefs, and perceptions" (Guskey, 2002, p.382). This implies that when teachers' attitudes, interpretations, and perceptions change they will result in improved classroom behaviour and student learning. Darling-Hammond and McLaughlin (1995) elaborated that teachers should be equipped with the knowledge and skills to be able to critically reflect on their practices during the process of professional development. Additionally, effective professional developmentdisplays a number of characteristics (Darling-Hammond & McLaughlin, 1995):

- It must engage teachers in concrete tasks of teaching, assessment, observation and reflection which will illuminate the process of learning and development.
- It must be grounded in inquiry, reflection and experimentation that are participant driven.
- It must be collaborative, involving a sharing of knowledge among educators and a focus on teachers' communities of practice, rather than on individual teachers.
- It must be connected to and derived from teachers' work with their students.
- It must be sustained, ongoing, intensive, and supported by modelling, coaching and the collective solving of specific problems pertaining to practice, and
- It must be connected to other aspects of school change (p.2).

Darling-Hammond and McLaughlin (1995) in their study established that for effective professional development, teachers must engage in real tasks, reflect on their activities and that observation plays an important role in teacher development. This implies that sharing, working collaboratively with peers, coaching and mentoring has become an important aspect in professional development. The study conducted by Easton (2008) reveals that teachers need to be involved in learning and need to know enough so that they will bring change and get different results. Easton further

explains that teachers must be experts in their subjects, initiate change and be able to develop themselves further.

Borko (2004) identifies professional development programs, facilitators, and context as the key elements for professional development. Consequently, there must be professional development programs, followed by teachers who are the learners while facilitators provide guidance to teachers since new knowledge is constructed as well as the context for professional development. This implies that for professional development to happen, four elements must be taken into considerations.

2.4 Professional Learning Communities

The concept of a professional learning community (PLC) is defined as a group of people coming together to share their skills, learning experiences and to logically examine their practices', reflect, and co-operatively work together to promote growth (Toole & Louis, 2002). According to Stoll (2012), PLCs consist of groups of teachers who actively work together to improve the learning of students. Likewise, (Harris, 2014 as cited in Wang, 2016, p.202) pointed out that a PLC is a "group of professional people working together as a cohesive team to address specific learner needs, arising from an analysis of data and evidence". PLCs must be established to promote teacher learning and to support teachers in their classroom practices. Hord (2009) defines a professional learning community as a cluster of teachers who meet frequently, work collaboratively, and share their expertise to expand their professional skills and development. Hord (2009) further discusses how professionals are the individuals that are passionate and dedicated with their work and they are liable for providing an effective instruction to students. He contends that learning is the process where professionals engage in activities which will improve teachers' knowledge and skills. Additionally, a professional learning community is defined as a group of people coming together in order to discuss significant activities. PLCs aim to build teamwork that supports continual learning which ultimately leads to the development of teachers and the improved learning of students.

Brodie and Borko (2016, p.9) describe the aim of PLCs as "to generate collective shifts in practice where all teachers pull in the same direction so that the learners' experiences are coherent". PLCs are designed to develop teachers' professionally and to improve learners' achievements. Additionally, they pointed out that the space for professional development must be provided by schools or outside the school, nonetheless "professional learning requires professionalspace and

time is necessary for ongoing, systematic professional learning" (Brodie & Borko, 2016,p.12). One may deduce that for PLCs to be successful, teachers must create space and time for their professional learning. Generally, PLCs, teacher learning communities (TLC) and CoP are used interchangeable by scholars. According to Chow (2016):

> The concept of teacher learning in a setting in which teachers come together over time for the purpose of reconsidering their existing beliefs and practice, gaining new professional knowledge and skills and reconstructing reform agendas that enhance student learning and professional practice.

This denotes that teachers in a PLC work collectively with each other with the aim of acquiring new knowledge and skills in order to improve the learning of students.

Matoti (2010, p.582) recommended "the creation of communities of practice, so that teachers do not suffer quietly" Henceforth, teachers learn together to make changes in their practice and knowledge is enhanced in professional learning communities. Vangrieken, Meredith, Packer and Kyndt (2016) established that PLCs and Community of practice (CoP) has a common aim, strategies and lot of similarities but there are differences in the definition and application. Vangrieken, et al. (2016) highlighted that in CoP, participants learn together, and they focus on problems related to their profession. Similarly, PLC promote professional development and focus more on collaboration. PLCs are used interchangeably with CoP. Hord (2009) contends that every context that supports the learning of professionals is called professional learning community. In relation to CoP, Lave and Wenger (1991) states that learning is situated in communities of practice which constitutes what and how is learned and teachers learned through participation in the practice. Further to this, he mentioned that communities are essential part of professional practice and professional learning. In addition, three features of communities of practice were identified namely: a joint enterprise, mutual engagement, and a shared repertoire. Wenger (1991) claims that though most of the communities made by people who are working together physical immediacy, but others might not share the same space but nevertheless may display these features.

The school-based PLCs is supported in Wang who declared that teachers from the same department and grade they should learn and work together as a group and addressing concerns related to

teaching and learning. Seashore, Anderson, and Riedel (2003) claim that PLCs designate the interest of establishment of a school culture that focus on encouraging teachers to work collaboratively share ideas, inclusive and systematically investigative their practice with the aim to improve student results. This is supported in Mason (2003) who says that professional learning communities and school learning organization "provide the structure and culture conducive to organizational learning by focusing on the following: teaching and learning, collaboration among staff and with external partners, inquiry-based learning and reflection, shared values, norms, dispositions of teachers, and continuous commitment improvement" (p.7).

The international study conducted in New Zealand found that making time for professional conversations, feedback, coaching, and mentoring are the important aspect of a school-based PLCs that supports mutual practices (Thornton & Cherrington 2019). These two researchers were investigating professional learning communities in early childhood education (ECE) within the schools. They also outlined the barriers in the establishment of PLCs this includes: "lack of induction for new members, staff changing membership, and lack of time for meetings, importance of relational trust for teachers to feel comfortable to engage in open discussion and reflection on their practices and the action of professional leaders" (p.420). Thornton and Cherrington (2019) established that leadership should be shared amongst members of PLCs. Trust is considered as the most important aspects for allowing healthy conversations. Thornton and Cherrington (2019) mentioned that willingness and time could not sustain early childhood education (ECE) PLCs. They highlighted factors that established and sustained PLCs in ECE, these factors include: "building trusting relationships, prioritising professional discussions and the deprivatisation of practice, taking ownership of the agreed focus and learning from the outside as well as the inside" (p.30). In this study they promoted the collective and supported learning where the senior teachers provide guidance in the novice teachers in order to sustain the ECE PLCs. Trust was the significant element in building the ECE PLCs. Members develop trust relationship and the discussions, engagement in the PLCs was prioritized and pays much attention on the agreed tasks.

There is also evidence from the international studies (Fullan, 1993; Murphy & Lick, 2001; Eaker, DuFour, & Burnette, 2002; King & Newmann, 2000; Glickman, 2002; Brandt, 2003) on teacher learning that support learning in PLCs that are outside of the schools. These studies have identified several features of PLCs such as inquiry-based, focused on student learning, goal-and results-

oriented, collaborative, reflective, based on shared values and beliefs and committed to continuous improvement. Czerniawski et al. (2018) looks specifically on the professional learning needs of higher education-based teacher educator. Even though my research specifically looks at mathematics teacher of grade 10-12, while this article is concentrating on tertiary teacher educator.

In South African context the policy for professional learning community (PLCs) were introduced in 2011 by the Department of Basic Education and Department of Higher Education and Training through the Integrated Strategic Planning Framework for Teacher Education andDevelopment. DBE and DHET (2015, p.14) define PLCs as "communities that provide the settingand necessary support for groups of classroom teachers, school managers and subject advisors to participate collectively in determining their own developmental trajectories, and to set up activitiesthat will drive their development". This stresses that PLCs were introduced to support teachers toimprove their classroom practices and teachers have to identify the areas of weaknesses and be responsible for their own development. Mkhwanazi (2014) states that in professional learning community teachers get the platform to have conversation with colleagues about their common classroom practice within or outside the school context. Furthermore, Mkhwanazi (2014) explained that in PLC teachers exchange ideas and reach same understanding in issues that are communal to them. Jita and Ndlalane (2009) highlight that teachers with high profile usually support their colleagues by engaging in a discussion of subject's concepts. In relation to this studya high profile could refer to senior teachers, cluster coordinators, workshop facilitators and lead teachers provide support to teachers. This corresponds with Mkhwanazi (2014) who contends thatin PLCs teachers learn from their colleagues and that enhances teacher knowledge, skills and improve proficiencies. Moreover, PLCs consist of the whole organisation or self-motivated team within the school (Wang, 2016).

A South African study Brodie and Borko (2016) suggests that in PLCs teachers must have the opportunity to discuss with one another and deliberately reflect on their teaching practice so that learners will benefit. The concern is more on the learning of teachers, often said that content knowledge is needed by the teachers. However, it is noted that the important parts of knowledge based is not recognized (Shulman, 1987). Brodie and Borko (2016) argue that PLCs need to be led by teachers who have support from districts and institutions of higher education in order for PLCs to become well-known and truly professional since PLCs are new in South Africa. Furthermore,

they argued that to sustain PLCs in schools and districts, stakeholders must regard PLCs as an ongoing priority for the district and resources for implementation of PLCs must be available. However, expert facilitators were needed to develop teachers in the PLCs to maintain a high level of professional development. Learning in PLCs was viewed as "fundamentally social and collective" (Brodie & Borko, p.9). This aligns with Stoll, Bolam, McMahon, Wallance, and Thomas (2006) who perceived learning in professional learning communities as fundamentally cooperative.

Brodie (2019) highlighted that there are challenges that have caused teachers not to participate in their PLCs. Firstly, the absence of their departmental heads in the PLCs and the lack of trust among members of the PLCs. He stated that time, resources, space, workloads and trust can influence teachers' participation in PLCs. The findings of the study conducted by Brodie indicated that teachers participated in the PLCs improved the way they tackled some mathematical problems in class and their professional identity changed since they have collaborated with other teachers. Furthermore, Brodie (2019) claimed that teachers changed the way they understand their learners after participating in PLCs.

Studies (Jita & Ndlalane, 2009; Mkhwanazi, 2014; Brodie & Borko, 2016; Brodie, 2019) on PLCs in South Africa have established that PLCs seems to enhance teachers' knowledge, skills and students learning or achievement is also improved. Most studies mentioned that it is important to create structures that support PLCs since they shape the school culture (Louis, 2002; DuFour, DuFour & Eaker, 1998). Likewise, Stoll et al. (2006) suggested that to be successful in a changing and increasingly complex world, the whole school communities need to work together to take charge of change, finding the best ways to enhance young people's learning. Huffman (2001) noted that a strong professional learning community involves all school stakeholders.

2.5 Teacher Cluster

Teacher clusters emerged from other countries where Lieberman and McLaughlin (1992) reported that teacher clusters can be dominant when teachers are provided with the opportunity to share vision, learning and share leadership. Reis, Gentry and Maxfield (1998, p.312) defined a cluster as a "group of teachers who shares a common interest and who come together during a specially designated time". Teacher clusters seems to offer teachers the opportunity to share knowledge and ideas with other teachers. Teachers in clusters share teaching resources, activities and teaching strategies with the aim of improving classroom practice (Reis, Gentry & Maxfield, 1998). They pointed out one of the challenges when organising a cluster workshop such as finding a time that works for all teachers. Leu (2004) highlights that a cluster is formed by a group of teachers from different schools working together with the aim of improving their practice. Teachers in clusters seems to collaborate, share resources, and reflect on their teaching practice. Reis, Gentry and Maxfield (1998) in their study on the impact of clusters found that teachers of the same grade were able to learn together, and their teaching practices improved. The findings of the study revealed that clusters have contributed to the learning of students and developing teachers' content knowledge. Reis, Gentry and Maxfield (1998) noticed that teachers enjoyed being part of the cluster workshop.

There are numerous studies on teachers' clusters conducted by different scholars in South Africa namely, Jita & Mokhele (2013), Jita & Mokhele (2014), Jita & Ndlalane (2009), Mitchell & Jonker (2013), Chikoko (2008), Brodie (2019) and Jita & Mokhele (2012). According to Makaye (2015) a cluster is a group of teachers from different schools brought together to share knowledge. Jita and Mokhele (2014) also described clusters as a group of teachers from different schools within one circuit. Jita and Ndlalane (2009) state that in clusters, teachers voluntarily work together as a group to engage in discussions on matters related to teaching practices. Mokhele (2013) also pointed out that teachers in subject clusters provide them with a platform to work with their colleagues and share the knowledge and skills. In the same vein, Mphahlele (2014) defined that clusters are systems of schools, where there is joint support between the teachers that belong to a certain group or cluster. Furthermore, clusters are networks of schools, where a particular group of teachers share common ideas.

However, Matoti (2010) perceived clusters as a tool for curriculum implementation whereas other researchers regard clusters as continuing professional development (Jita & Mokhele, 2012). Muijs (2008) indicated that members of cluster do not experience difficulties when a new curriculum is implemented because teachers work collaboratively. Further to this, teachers from disadvantaged areas benefit more when teachers exchange expertise, share knowledge, skills, and resources. In addition, Muijs (2008) concluded that teacher clusters in South Africa are regarded as a potential strategy to improve schools and increases teacher professional development. The professional development of teachers is promoted in clusters because it improves their classroom practice and the learning of students (Villegas-Reimers, 2003). Clusters are used as a tool to promote collaborative learning and build a team spirit amongst teachers.

Teacher cluster networks are perceived as connected or exchangeable. This is emphasised by Jita and Mokhele (2014, p.3) who stated that in the international context, "teacher networks, federations and clusters are regarded as related concepts, although they have different nuances and implications". Similarly, Giordano (2008) stated that clusters are intended to support individual teachers to work collaboratively. In addition, teacher networks are viewed as Teacher Learning Communities (TLCs) or Communities of Practice (CoP) (Jita & Mokhele, 2014). Communities of Practice (CoP) are taken from Wenger (1998). This was supported by Mitchell and Jonker (2013) who stated that teacher clusters are the best model for the communities of practice.

Mokhele (2013) led a study in Mpumalanga Secondary Schools Initiative (MSSI) in South African context. This study investigated how mathematics and science teachers engaged in professional development in clusters. The MSSI was used a cluster approach where the collection of teachers from different schools, grades and department works together in small groups to discuss matters concerning learning and teaching of science and mathematics. In line with Muijs (2008) and Marneweck (2002), Mokhele's (2013) findings of the study show evidence that teachers in clusters gained new knowledge and skills by sharing information with their colleagues.

In the article, "When teacher clusters work: selected experiences of South African teachers with the cluster approach to professional development" (Jita & Mokhele 2014, p.1). They highlighted that teacher clusters replaced the cascade approach (where the head of department is trained by subject advisors who then trained the subject or classroom teacher) (Jita & Mokhele, 2014). The study explored teachers' viewpoints on what constitutes an effective teacher cluster. They found

that a teacher cluster appears to "enhance teachers' content knowledge and pedagogical content knowledge (p.6)". The findings of their study pointed out that teachers benefitted by having the opportunity to share or reflect on their teaching experiences and work collaboratively with one another.

According to Jita and Mokhele (2014, p.4) "teachers in cluster communicate, share, and address issues, observe one another's work and develop expertise in various aspects of their teaching practice". They highlighted the three-key benefits of clusters that work is "teacher collaboration, instructional guidance and teacher leadership and they refer as a process benefits" (Jita & Mokhele, 2014, p.7). This emphasizes the significance of sharing of ideas, knowledge, and skills; improving the instructional guidance in classroom practice and the dissemination of power. Additionally, they mentioned the activities that improve teacher instruction and student performance which include "curriculum analysis, lesson planning, lesson presentation, assessment, lesson studies, sharing ideas on CK and PCK (p.11)". They believed that all these activities mentioned have a good impact on improving teacher practices and the learning of students. Jita and Mokhele (2014) who stated that teacher clusters allow teachers to look at challenges they experienced in their classroom practice and thus CPD is promoted alone or collectively. Additionally, Jita and Mokhele (2014) stated that, the ingredients for a successful teacher cluster is teacher collaboration as Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) are enhanced.

Mitchell and Jonker (2013) advocated that clusters are one of the platforms of sharing problems faced by teachers and experiences about their practice. A study by Mitchell and Jonker (2013) focuses on psychosocial issues within the school context and not in mathematics and science. The findings of the study confirm that clusters empower teachers with knowledge and new information and become an agent of change for their communities. Teachers benefits from 'self-sustaining teacher clusters in various ways including "networking, personal development, implementation of new skills and information, develop each other academically, financially and emotionally development" (p.109). In addition, they mentioned the success factors of teacher networks which include "the sense of collegiality that developed, ownership of the process and participation as peers, and a sense of resourcefulness within the group" (Mitchell & Jonker, 2013, p.103). They emphasised the usefulness of teacher networks whereby teachers work together with their colleagues, exchange resources and experience teamwork. This is supported by the findings of a

study conducted by Zulu and Bertram (2019) which revealed that mathematics teachers collaborated inside and outside the workshops where teachers' share resources and skills. Teachers were working in groups and in pairs to support one another.

International and South African literature in this section found teacher clusters as the most popular forms of continuing professional development (CPD) in South Africa where teachers share a common purpose as well as knowledge and beliefs. it has also been noted that teacher clusters improve classroom practices and learner achievements (Jita & Mokhele, 2014). This literature explained that teachers learn collaboratively with their colleagues, share common ideas, and acquire the necessary knowledge in clusters that led me to explore teacher learning in a mathematics cluster as a professional learning community. This study was interested in exploring how mathematics teachers learn in a cluster and the type of mathematics knowledge they learn. The study is also interested in finding whether the mathematics cluster adheres to the features of a PLC. Clusters has been considered as a way of developing teachers, curriculum and improving the learning of students.

2.6 Conceptual Frameworks

This study adopted three conceptual frameworks; Birman, Desimone, Porter, and Garet's (1999) elements of designing professional development that works; Ball, Thames, and Phelps' (2008) domains of mathematics knowledge and Stoll, Bolam, McMohan, Wallance and Thomas' (2006) features of PLCs.

2.6.1 Birman, Desimone, Porter, and Garet (1999) elements of professional development

Birman, et al. (1999) identifies six elements that can be used when exploring studies related to teacher development, with a specific focus on mathematics and science. These elements are further divided in two groups: structural and core features. The structural group includes "form, duration and participation" looks at (Birman, et al., 1999, p.29). The core group consists of "content focus, active learning and coherence".

2.6.1.1 Structural features

Birman, et al. (1999) recommended the following structural features as the tool that set the context for professional development:

Form: This refers to the structure, which can be divided into either traditional (workshops) or reform (teacher networks). The latter is associated with activities such as study groups or teacher networks. The former is associated with either workshops or conferences. Birman (et al., 1999) pointed out that literature on professional development suggested the need to rethink approaches, especially the traditional one because they are less effective. Birman, et al. (1999) mentioned that "traditional workshops are criticized for not giving teachers the time, the activities and the content necessary for their knowledge and for fostering meaningful change in their classroom practice" (p.29). Reform activities are more about the learning of teachers and the influence is more on improving their classroom practices.

Clusters can be classified as a form because clusters provide a network for teachers to support one another through collaboration. Teacher networks seems to empower teachers with the necessary skills and knowledge. Borko (2004) declared that the programmes for professional development help teachers to improve their knowledge and their classroom teaching. Similarly, Desimone, et al. (2006) stated that effective professional development provides teachers with the relevant skills and knowledge while teaching practices changed and student achievement also improved. The findings from Jita and Mokhele (2014) provided evidence of activities that occurred in teacher clusters such as teachers having discussions with their colleagues and re-examining content knowledge (CK) and pedagogy content knowledge (PCK) (Shulmans, 1987). Secondly, teachers work collaboratively on issues related to subject matter, their instructional guidance and teacher leadership improved. Thirdly, teachers engaged in activities where they planned or prepared together and helped one another with curriculum issues. Fourthly, teachers in clusters shared ideas and about the way they approach challenging topics, teaching aids, how they identify problematic sections and try to work on solutions.

Duration specifically looks at how long the activity will take for example Birman, et al. (1999, p.30) indicate that activities of longer duration have more subject-area content, more opportunities for active learning, and more coherence with teachers' other than shorter activities. This

characteristic will help me to see the activities that have more subject-area content and the activities that create the opportunity for teachers to be more active.

Participation, Birman, et al. (1999) stated that participation occurs when teachers from different schools participate collectively with other teachers. The advantage of collective participation is that it allows teachers to discuss problems arising during staff development. This implies that teachers from different schools with different ideas participate collectively in clusters. Teachers also get an opportunity to collaborate with other teachers. I will use this feature to observe how mathematics teachers from different schools participate in the Siyakhula cluster.

2.6.1.2 Core features

The core features are intended to identify all the processes or developments that occurred throughout the professional development.

Content focus: focuses on the efforts for improving teacher content knowledge. "It is the degree to which professional development focuses on content knowledge which directly related to teachers reported increase in knowledge and skills" (Birman, et al., 1999, p.30). Birman, et al. (1999) stressed that teachers' professional development should increase the content knowledge of teachers and understanding while not focusing on teaching techniques. The content of activities was further described through the mathematics knowledge conceptual framework. Content focus helped me to understand how mathematics teachers learn in a cluster and activities that help teachers to improve & deepen teachers' content knowledge.

*Active learnin*g looks at how the teachers engaged meaningfully with the process of teaching and learning e.g. through an assessment of their students' work and obtaining feedback about the way they teach. Teachers whose professional development includes opportunities for active learning reported increase knowledge and skills and changed classroom practice (Birman, et al., 1999).

Coherence: This is when one wants to see if activities used for professional development were able to make teachers continue professional communication and able to generate experiences "consistent with teachers' goals and aligned with state standards and assessment" (Birman, et al. 1999, p.29). Through coherence, Birman et al. (1999) in their study on professional development, were able to understand the alignment of professional development with policies and other related professional experiences that improves teacher learning and their classroom practices. Using this feature will help to check whether teachers transferred knowledge, skills and ideas learnt in clusters

into their classroom practices. Birman, DeSimone, Porter, and Garet's (1999) professional development frameworks helped me to understand how mathematics teachers learn in a cluster.

2.6.2 Ball, Thames, and Phelps' (2008) domains of mathematics knowledge

In this section I have drawn the information from Ball et al. (2008) domains of mathematics knowledge. Shulman and Sykes (1986, p.5) outlined "the knowledge base of teaching as that body of understanding and skill, of dispositions and values, of character and performance that together underlie the capacity to teach".

Ball, Thames, and Phelps (2008, p.403) introduced domains of mathematical knowledge for teaching. Ball, Thames, and Phelps (2008) derived their mathematics domains from Shulman's (1987) because of their belief that it bridges content knowledge and the practice of teaching. They discussed that mathematics teachers need to know everything in the curriculum and issues related to pedagogical content knowledge.

Ball, et al. (2008) categorised domains of mathematical knowledge for teaching the subject namely: Common Content Knowledge (CCK); Horizon Content Knowledge (HCK); Specialised Content Knowledge (SCK); Knowledge of Content and Student (KCS); Knowledge of Content and Teaching (KCT) and Knowledge of Content and Curriculum (KCC). Ball, et al. (2008) pinpoints two domains that was identified by Shulman (1986) such as "knowledge of content and student and knowledge of content and teaching" (p.402). They used these domains of knowledge to elaborate subdomains by evaluating and endorsing knowledge.

Common Content Knowledge (CCK)	Specialised Content Knowledge (SCK)	Knowledge of Content and Student (KCS)	Knowledge of Content and Curriculum (KCC)"
Horizon Content Knowledge (HCK)		Knowledge of Content and Teaching (KCT)	

Figure 1: Domains of Mathematical Knowledge for Teaching Ball, et al. (2008, p.403)

2.6.2.1 The Common Content Knowledge(CCK)

The Common Content Knowledge (CCK) includes the skill of identifying wrong answers and incorrect definitions given by students, and the talent of resolving students' problems (Carrillo, Climent, Contreas and Munoz-Catalan, 2013). Teachers have to know the students they teach and write the correct notation on the board (Ball, et al., 2008). Ball et.al (2008) further mentioned that CCK comes when posing a question such as: "what is a number that lies between 1.1 and 1.11, asking a question that require knowing that a square is a rectangle, that 0/7 is 0 and that the diagonals of a parallelogram are not necessarily perpendicular" (Ball et al.,2008, p.391). These questions would be answered by someone who knows mathematics. This domain will be useful for checking whether teachers in clusters demonstrate the skills of resolving student problems and identifying the wrong answers.

2.6.2.2 Specialised Content Knowledge (SCK)

Specialised Content Knowledge (SCK) involves unique skills for teaching, mathematical knowledge and the skill to do challenging questions that another student cannot do. Ball et al. (2008, p.400) claim that "teaching requires knowledge beyond that being taught to students, because it requires understanding different interpretations of the operations in ways that students

need not explicitly distinguish; requires appreciating the difference between measurement and partitive models of division". Teachers must unpack mathematical knowledge and simplify problems in order for students to understand and explain the use of mathematical language. Teachers must demonstrate creativity when teaching challenging topics.

2.6.2.3 Knowledge of Content and Students (KCS/KCT)

This knowledge combines knowing mathematics and students simultaneously. Knowledge of Content and Teaching (KCT) involves knowing about content and teaching Ball, et al. (2008). Teachers need to anticipate the thinking of students and what will be unclear to students. When an activity is given to a student, teachers need to predict the mathematics problems that students will find motivating and interesting. Carrillo, et al. (2013) concur that teachers presume what students willfind simple or difficult in given tasks. Furthermore, Ball, et al. (2008) stated that teachers must have the knowledge of mathematical content and be able to identify incorrect answers. Teachers must recognize the common errors student are likely to make.

The mathematical activities require mathematical knowledge and teachers to choose the examples they will use in the introduction and examples to understand the content. Teachers chooses the instructional method that would best fit the students and "during a classroom discussion, a teacher must decide when to pause for more clarification, when to use a student's remarks to make a mathematical point, and when to ask a new question or pose a new task to further students' learning" (Ball, et al., 2008, p.401). He also argues that teachers must use the teaching models for example, in subtraction, money can be used.

2.6.2.4 Knowledge of Content and Curriculum (KCC/HCK)

"Horizon Content Knowledge (HCK) and Knowledge of Content and Curriculum (KCC)" focus both on the curriculum and content (Ball, et al., p. 403). Horizon content knowledge (HCK) includes the knowledge of teachers and how mathematics is allied across the curriculum grades (Ball et al., 2008). Teachers are interested to know what is happening in the next grade so that they will prepare students for that grade. This resonates that mathematics teachers should be aware of the curriculum for the following grade so that they can prepare learners with the relevant information. The basic knowledge for the previous grade will help students and teachers to build up new knowledge for the current grade.

Additionally, Knowledge of Content and Curriculum includes teacher knowledge about mathematics content in relation to resources that support learning such as textbooks or study guide (Ball et al., 2008). For example, this knowledge will assist in selecting the appropriate resources for students such as choosing the correct scientific calculators that help student in plotting graphs, financial mathematics, statistics, and probability. Tamir (1988) adds that mathematics teachers use this knowledge in their teaching and the usefulness of curriculum knowledge for mathematics which includes, knowledge of texts, materials, resources, tests, syllabus, and examinations. Shulman (1987) stated that these types of knowledge are important. Therefore, the knowledge of content and curriculum will be useful in teaching the subject, this knowledge was considered significant.

Additionally, Earnest (1989) suggested that mathematics teachers must have the knowledge of classroom management, activities, questioning, excursions, records keeping, classroom testing and so forth. He further stated that knowledge of the context of teaching is important which includes knowledge of other teachers, classrooms, departments, policies, knowledge of the students and school locations. Furthermore, knowledge of education is identified as the most important because it enable teachers to interpret classroom experiences, reflect and plan. Knowledge of education includes "theories, concepts, empirical results and other knowledge acquired from literature" (p.19). Ball, Thames, and Phelps (2008) domains of mathematics knowledge was used to describe the kinds of knowledge they acquired through the activities of the cluster.

2.6.3 Stoll, Bolam, McMohan, Wallance and Thomas' (2006) Features of Professional Learning Communities

Stoll, Bolam, McMahon, Wallance and Thomas (2006, p.226-227) identified seven characteristics of PLCs namely: shared values and vision, collective responsibility, reflective professionalinquiry, collaboration, regularity, promotion of group and individual learning and distributed leadership. Other research scholars such as Van Blaere and Devos (2015) and Carpenter (2014) have elaborated on the aforementioned features of PLCs. Interestingly, the South African Integrated Strategic Planning Framework for Teacher Education and Development (DBE & DHET, 2011) is aligned to the international literature on PLCs.

2.6.3.1 Shared values and vision.

The shared vision and the sense of purpose is important in the PLC. Stoll, Bolam, McMahon, Wallance and Thomas (2006, p.226) advocate that "a shared value base provides a framework for shared collective, ethical decision making," This statement resonates with DuFour and Eaker (1998), Hord (2004) who established that members of PLCs are equally in charge, accountable and values are shared. This suggests that teachers should be part of the decision making in PLCs. Furthermore, similarities must be shared that classifies you as a member of one community thus, shared vision develop teachers and improve student learning (Van Blaere & Devos, 2015). This is supported in the South African policy context (DBE& DHET (2011) that a shared vision and clear focus on safeguarding learning for pupils, constitute highly quality teaching and learning. In addition, shared vision means that members of the community share ideas, thoughts and all members have equally responsibility.

2.6.3.2 Collective responsibility.

Collective responsibility in a PLC implies that members of the community come together to form a collective understanding of how all their learners learn, and to improve it (DBE & DHET 2011, p.14). This stresses that members of PLCs should take collective responsibility in the learning of students. Problems are solved by teachers with the intention to enhance student achievement (DuFour, et al. 2008).

2.6.3.3 Reflective professional inquiry.

Stoll, et al. (2006) call it is a reflective dialogue, because it includes conversation about serious education issues or problems concerning the application of new knowledge in a sustained manner. He further explained that PLC members take "collective responsibility for student learning" (Stoll et al., 2006, p.226). Furthermore, conversation entails of the examining of teachers practice, joint planning of curriculum development and "tacit knowledge constantly converted into shared knowledge" (Stoll et al., 2006, p.226). Collective responsibility sustains the commitment on student and accountability.

2.6.3.4 Collaboration.

Collaboration is the core feature of a PLC. It includes teachers involved in "developmental activities with consequences for several people, going beyond superficial exchange of help, support, or assistance" (Stoll, et al., 2006, p.227). During collaboration teachers work together and share the information about their classroom practice and the influence of professional practice is analysed in order to improve the performance of students (DuFour, et al., 2008). McLaughlin and Talbert (2006, pp.3-4) designate PLCs as "organizational structures in which teachers work collaboratively to reflect on their practice, examine evidence about the relationship between practice and student outcomes, and make changes that improve teaching and learning for the particular students in their classes" This suggest that teachers in PLC work together to improve their teaching and learning which could lead to changes in their classrooms, teaching and doings.

2.6.3.5 Regularity

This feature put emphasis on the regularity of the workshops or meetings for PLCs. The meetings of PLCs can be formal or informal. Knapp (2003) proclaimed that professional development involves structured experiences and unstructured experiences. Meeting can be structured or unstructured. According to William (2007) members of PLC meet regularly to engage in discussion about tasks and topics in order to effect changes in teaching and learning. Calhoun and Green (2015) alluded to the online professional learning communities instead of physical meetings.

2.6.3.6 Leadership

Distributed leadership mean that leadership is spread amongst all the members of PLCs. This concurs with Carpenter (2014) who declared that leaders can share responsibility in order to improve teachers' knowledge and achievements of students. The PLCs have facilitators who make sure that the meetings happen, the venue for the meeting is organised, etc. Importantly, distributed leadershipin the PLC is a "powerful lever" (Priestley, Miller, Barret & Wallace, 2011, p.269) in developinginnovations in PLC. Priestley et al. (2011) argue that for innovations to take place in PLCs leaders should assume collegial figures rather than authoritarian leaders. Additionally, leaders of PLCs also need skills and knowledge to plan proper activities for the teachers (Brodie 2013).

2.6.3.7 Group, as well as individual, learning is promoted

This feature integrates individual and collective learning. According to Stoll, et al., (2006, p.227) "all teachers are learners with their colleagues and collective learning is also evident, through collective knowledge creation whereby the school community interacts, engages in serious dialogue and deliberates about information, and data, interpreting it communally and distributing it among them". This implies that teachers learn in interaction with students, colleagues, and experts. Individual learning is encouraged when teachers interact with the resources such as textbook, exercise, models and writing tests. These seven features of PLCs discussed in this section were used to describe the extent at which the mathematics cluster operates as a PLC.

2.7 Conclusion

In summary, this chapter discussed literature in relation to teacher learning and defining key concepts surrounding teacher learning, professional development, professional learning communities, clusters, and conceptual frameworks used in this study. The following chapter discusses the research design and methodology of this study.

CHAPTER THREE
RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Chapter Two articulated existing debates in literatures related to teacher learning, professional development, professional learning communities, clusters, teacher knowledge and conceptual framework that underpinned the study. This chapter describes and justifies the research design and methodology which were selected to examine teacher learning in a mathematics cluster as a professional learning community. The chapter discusses the research approach, research paradigm, sampling procedure, data collection tools, data analysis, trustworthiness, ethical consideration, my role, and limitations of the study.

3.2 Research Approach

The qualitative research approach was employed in this study to explore how teachers learn in a mathematics cluster as a professional learning community. Creswell (2008, p.15) defines qualitative research as a process of understanding based on distinct methodological traditions of inquiry that explores social and human problems. Similarly, Ary, Jacobs, and Razavieh (2002, p.22) state that "a qualitative research approach focuses on understanding social phenomena from the perspective of the human participants in the study" (p.22). Creswell (2008) also pointed out that qualitative research is grounded in discovering and understanding an individual or group. Creswell (2007) adds that qualitative research is a type of educational research in which the researcher relies on participants' views where the researcher asks broad questions, and the generated data largely consists of words for themes and the inquiry is conducted in a subjective manner. Therefore, in this study I depended on participants' perceptions and their understanding of how and what they learn in a mathematics cluster. Furthermore, a qualitative research approach is regarded as the investigation whereby the researcher gathers the information during the progression of interrelating with participants (McMillan & Schumacher, 2010). Teherani, Wadhwa and Varpio (2015), elaborate by saying that a qualitative research approach "is the systematic inquiry into social phenomena in natural setting" (p.668). The phenomena include the experiences of people and how groups or individuals behave or functions of organisations. Furthermore, Mouton (2011) mentioned that qualitative research approach tries to understand and describe the

phenomenon. Teherani et al. (2015) also stated that the researcher in a qualitative study investigates why the events happen and finding the significance what those events mean to the participant studied. They further highlighted that qualitative research approach gives the respondents a room to elaborate their views and the questions modified by the researcher. In line with these authors this study is concerned in investigating how the individual teachers in a mathematics cluster learn, studying teachers' experiences and knowledge learnt and interpret their learning experiences.

Chilisa and Preese (2005) maintain that qualitative research approach is an enquiry whereby the researchers seek information about the experiences of people in their environment by using instruments such as observations and interviews. In addition, Creswell (2003) concur with Denzil and Lincoln (2006) who asserts that researchers are allowed to obtain the verbal descriptions and participants interpretations in a qualitative approach. Additionally, qualitative research approach relies on the emphasis on lives experience of peoples', views, assumptions, predeterminations and presumptions (Amaratunga, Baldry, Sarshar, & Newton, 2002).

Qualitative research is guided by ontological assumptions which assume that reality is subjective and capable of sustaining multiple interpretations (Cohen, Manion, & Morrison, 2018). The epistemological assumption of qualitative research is based on "behavior, and thereby, data are socially situated, context-related, context-dependent and context-rich" (Cohen et al., 2018, p. 288). The researcher concentrates more on subjective accounts, interpretations and views of phenomenon by the participants.

Elliot 1999 as cited in Elliot and Timulak (2005, p.147) describe qualitative research features as:

- Emphasis on understanding phenomena (rather than from some outside perspective).
- Open, exploratory research questions (vs. closed-ended hypotheses).
- Unlimited, emergent description options (vs. predetermined choices or rating scales)
- Use of a special strategy for enhancing the credibility of design and analyses.
- Definition of success conditions in terms of discovering something new (vs. confirming what was hypothesized).
- Data are descriptive and pictures used rather than numbers.

- Focuses on naturally occurring, ordinary events in natural settings, so that there is a view on what "real life" is like (Amaratunga et al., 2002).
- Richness and holism, with strong potential for revealing complexity (Amaratunga et al., 2002).

Qualitative researchers explore how people describe and understand a phenomenon through the assigned meaning (Maree, 2011). Furthermore, the qualitative research approach aims at understanding the society actions and avoid generalisations to the wider community (Mouton, 2011). In line with Mouton (2011) the qualitative approach was suitable for this study because I was motivated to explored teacher learning in a mathematics cluster, observed how teachers engaged in activities collectively and understand how they learn. Textual data was collected in this study where participants learned jointly and participated in all cluster's activities. The qualitative research approach was suitable because I investigated the phenomena of teacher learning through assembly information comprises of detailed explanations, understandings, and interpretations of teachers. I investigated how mathematics teachers learn in clusters.

3.3 Research Paradigm

The study adopted an interpretive paradigm because the interpretation of world is viewed from participant's perspective (Cohen, Manion, & Morrison, 2011). The concern of this study was the interpretations of subjective experiences of individuals, which are mathematics teachers in Siyakhula cluster (pseudonym) in uMgungundlovu district. This paradigm focused on understanding and describing meaning of social action (Cohen & Manion, 1994). Using this paradigm, I gained the insight about mathematics teachers' experiences about teacher learning in clusters. Additionally, in the interpretive research paradigm, the individuals' perspectives, behaviours, experiences and attitude are studied Cohen et al. (2011).

According to Creswell (2012) the interpretive paradigm is grounded on the beliefs that multiple realities exist. Furthermore, the interpretive paradigm understands human experiences and suggesting that "reality is socially constructed" (Mertens, 2005, p.12). The epistemological assumption of the interpretive paradigm (nature of knowledge) is that knowledge is interpretive socially constructed by those in the research process (Creswell 2007, Robinson, 2002). The association between the participants and myself through interviews enabled me to understand the participant's multiple experiences from their point of view. According to Cohen, Manion, and Morrison (2007) "interpretive paradigm is characterised by a concern for the individual, aims to

understand from within the subjective world of human experience and, focuses on actions to ascertain the intentions of actors to share their experiences" (p.21). The interpretive paradigm was most suitable for this research study because the researcher depended on the views and experiences of mathematics teachers to obtain understanding of clusters as a PLCs.

The interpretive paradigm aims at understanding how participants perceive and interpret the world. Participants had their own way of explaining their realities where they work and then, the choice of using the "interpretive paradigm is ontologically based on the assumption that humans create meaning and make sense of their worlds" (Neuman, 2000, p. 85). Then, the interpretive paradigm used in this study opened the opportunities for teachers to elaborate on their views based on teacher learning in clusters, experiences and expressed themselves. Maree claimed that "the aim of interpretivist research is to offer a perspective of a situation and to analyze the situation under study to provide insight into the way in which a particular group of people make sense of their situation or phenomena". In addition, the interpretive paradigm used some methods to generate data which includes interviews, observations note and document analysis (Cohen, Manion, & Morrison, 2012). Henceforth, these mentioned methods were used in this study in collection of data.

3.4 Research Design

This study used a case study research design. The case study is an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p.13). Rule and John (2011) define a case study "as a systematic and in-depth investigation of a particular instance in its context in order to generate knowledge" (p.4). This is supported by Thomas (2011) who also defines a case study as a detailed study which focuses on a particular phenomenon viewed from numerous angles/viewpoints. This viewing of the phenomenon in multiples angles is in line with the interpretive paradigm and qualitative research approach employed in this study. The aim of the case study is investigating contemporary phenomenon and finding in-depth knowledge (Rule & John, 2011). Similarly, this study aimed at finding detailed information about teacher learning in grades 10-12 of a mathematics cluster as a professional learning community in uMgungundlovu district. The case in this study was mathematics teachers in a cluster and the phenomenon was teacher learning.

Stake (1995) and Yin (2003) uses different categories to classify the types of case studies, Stake's (1995) classification of the types of case studies include intrinsic, instrumental, and collective case

studies. According to Stake (1995), in an intrinsic case study a researcher is determined to understand a particular case and has a genuine interest in the case. In an instrumental case study, the researcher is usually trying to achieve something rather than understanding a particular situation as well as providing insights and helping to refine a theory (Stake, 1995). He also explains a collective case study as one which normally involves multiple case studies to gain an in-depth understanding. This study relates to an intrinsic case study design because the researcher wanted to understand how mathematics teachers learn in a cluster and the interest came from the researcher for conducting the study. Yin (2003) classified case studies into three categories, namely, exploratory, explanatory and descriptive. Cohen, et al. (2018, p.377) discuss that an exploratory case study "can be used to generate hypotheses that are tested in larger-scale surveys, experiments or other forms of research, for example, observational". According to Yin (2003) an exploratory case study is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes. The study adopted an exploratory case study because the researcher wanted to explore how grade 10-12 mathematics teachers learn in a clusters and to gain a deeper understanding of the types of knowledge teachers acquired in the Siyakhula cluster.

Stake (1995) highlighted the features of a case study involve a detailed intensive inquiry reflecting a rich and lively reality of the case and is precise since the number of units to be studied is small. The researcher is intrinsically involved in the case and gives details to generate from a single example necessitates an in-depth inquiry of the interdependencies. The researcher can inquire about an individual, communities and programs. The case study focuses on "how" and "why" question (Yin, 2003). Similarly, Cohen et al. (2007) stated that case study may be well-defined by the characteristics of the individual, group or cluster and have boundaries that allow for that definition. In a case study, detailed information is collected that other research design could not have obtained. A case study highlights specific events that are related to the case and studies a social unit deeply and thoroughly (Yin, 2003). In addition, the collected data in a case study usually has detailed information compared to other research designs. In this study, I did not interfere with the participant's behaviour and was not a participant.

The strength of a case study research design is that it allows the researcher to get close to the area of interest (Rule & John, 2011). The theoretical insight is generated by using a case study. In addition, different methods strengthen the case study which includes semi-structured interviews, observations and documents analysis (Yin, 2003). By adopting these data generating methods, I managed to obtain rich and thick descriptions of teacher learning. The benefits of a case study include the close relationship between participants and the researcher which encourages the participant to tell their stories (Yin, 2009). These good relationships have helped the researcher to understand their participants' behaviour (Yin, 2009). Therefore, the data was detailed and ready for analysis.

The researcher adopted a case study research design with the aim of gaining a deep insight and comprehensive understanding of teachers' activities taking place in clusters. This assertion was supported by Rule and John (2011, p.105) who "articulated that a case study is fit for the purpose of generating in-depth, holistic and situated understandings of phenomena". A case study was most suitable because it allows for the exploration of the individual case focusing on a single unit (Cohen, et al., 2007). Furthermore, the study used multiple methods of data collection therefore, a case study was suitable for this study (Cohen et al., 2018). Drawing from the discussion, I found a case study research design very suitable for the study.

Conversely, there were some limitations to case study research design. The data collected using a case study as a research design cannot 'necessarily be generalised to the wider population' and researchers have little control over certain variables (Yin, 2003). Case studies normally include only one person which could cause biased verification since the researcher may be both a participant and an observer. In addition, to draw a definite cause and effect in the conclusion is very difficult when using a case study (Denscombe, 2014). "Participants are very likely to experience negative feelings of upset and nervousness when discussing and reflecting upon sensitive aspects of their life in an interview procedure" (Cohen et al., 2018, p.378). A case study is likely to collect mostly qualitative data.

3.5 Sampling Procedure

Purposive sampling was used in this study (Cohen et al., 2011). According to Bertram and Christiansen (2014), purposive sampling means that "the researcher makes specific choices about

which people, groups or objects to include in the sample" (p.60). In addition, the sample size is ordinarily small and is not aimed at generalizing because the targeted group only represents itself, it does not represent the wider population (Cohen, et al., 2011). Siyakhula cluster (pseudonym) under uMgungundlovu district was purposefully selected. One mathematics cluster was selected for the study. The selection of the Siyakhula cluster was driven by the need for the research topic. The research wanted to find how mathematics teachers learn in a professional learning community. This cluster was selected because they had grades 10-12 mathematics teachers, they attended different workshops as qualified mathematics teachers. The study targeted all mathematics teachers in a cluster.

Purposive sampling was used to select participants of the study as I believed that they possessed information which would answer the three research questions of this study. I invited well-informed people who have a comprehensive understanding of learning in the Siyakhula cluster. The study invited three mathematics teachers and the subject advisor for interviews. Participants were chosen according to their portfolios in the cluster namely, a mathematics cluster coordinator and two lead teachers that were selected according to their teaching experience and mathematics cluster activities. All the individuals who were selected for interviews were purposefully chosen due to their position, experience, and success as teachers. Additionally, the Siyakhula cluster had 12 schools with 21 teachers who meet once per term. Table 1 on the next page shows the biographical information about the participants.

Name	Age Range	Gender	Qualifications	Teaching Experience	Years involved with the Cluster	Portfolio in the mathematics cluster
Khenani	35-39	Male	National professional diploma in education, B.Ed. Honours in mathematics, B.Ed. Honours in management	13 years	10	Portfolio in the mathematics cluster
Phumzile	50-55	Female	Senior teachers' diploma, ABET and B. Tech Management in Education.	30 years	16	Lead teacher
Neleh	30-35	Male	B.Ed. degree	8years	8	Cluster coordinator
Tholah	40-45	Female	Chemical Engineering and PGCE	15 years	13	Lead teacher

Table 1: Biographical details of the interview participants from the mathematics cluster

3.6 Profile of the Participants

The biographical information discussed in this section include participants' teaching experience, age range, grade taught, qualifications and portfolio in the cluster.

3.6.1 Khenani

Khenani is between 35-39 years old. He is a professionally qualified teacher, and holds a National Diploma in Information Technology (IT), a National Professional Diploma in Education majoring in mathematics and physical science, an Advanced Certificate in Mathematics, Bachelor of Education (B.Ed.) Honours in mathematics, B.Ed. Honours in Management, a Project

Management certificate, and he has other certificates for participating in the mathematics project. He has 13 years' experience in teaching mathematics, and he became the subject advisor in 2015. He is not teaching any grade. When he discussed his portfolio, he said:

> *I am a subject advisor and monitors this mathematics cluster. I am responsible to moderate content workshops, controlling teachers work. I also set the cluster activities, facilitate memorandum discussion, help teachers with marks allocation in the School Based Assessment (SBA) tasks. I help teachers with setting of tasks, this year we set a provincial common task for grade 10, 11 and 12 investigations to assist teachers since we have noticed that in previous years' investigation was not correctly set and conducted.*

3.6.2 Neleh

Neleh is a male teacher between 30-40 years of age. He is a professionally qualified teacher and has a Bachelor of Education majoring in mathematics and physical science. He has eight years' experience in teaching mathematics. He has been coordinating the mathematics cluster from 2016 up to date. He is teaching mathematics in grade 9, 11 and 12. Neleh explains his portfolio in the mathematics clusters:

> *I am a cluster coordinator, from 2016 up until today. I set tasks for cluster and distributing to other schools so that we can do a uniform task and moderate when we meet for moderation for those tasks, examinations for example March Tests, June and September Examinations. I moderate teachers work and sign their file. I set the cluster activities and then distribute these activities in their schools. I am also a facilitator in the DBEworkshops. I also give clarity on mathematics topics where teachers they do not understandor may be to help them but if I failed the problems are then transferred to subject advisors.*

3.6.3 Phumzile

Phumzile is a female between 50-55 years of age. She is a professionally qualified teacher, and she holds a Senior Teachers Diploma, in Adult Basic Education and Training (ABET) and Bachelor of Technology (B. Tech), Management in Education. She majored in mathematics and geography. She has 30 years of experience in teaching mathematics. She is a cluster secretary and a lead teacher since 2018. She is teaching mathematics in grade 8, 10 and 12 this year. Phumzile gives details about her portfolio in the mathematics cluster:

As a secretary, I write minutes and I also write invitation to the teachers, sometimes I write them, or I send emails or send sms, I believe in using WhatsApp. I am also a lead teacher, it is a good experience, I help other schools that underperforms in mathematics, I teach their learners during weekends and school holidays, and I marked the pre and posts tests written by learners.

3.6.4 Tholah

Tholah is between 40-45 years of age. She is a professionally qualified teacher and has obtained a Bachelor of Technology in Chemical Engineering and a Post Graduate Certificate in Education (PGCE). Her major subjects are mathematics and physical science. She has 15 years' experience teaching mathematics. In this cluster, she has been a lead teacher since 2017 and is currently teaching grades 11 and 12. She reported that her results from Grade 12 are consistent good results, and then the mathematics subject advisor nominated her to coordinate team teaching among the schools in Siyakhula mathematics cluster. Tholah described her portfolio in the mathematics cluster:

I am a lead teacher, and I am also coordinating team teaching. So as lead teacher we help schools that did not perform very well in mathematics. For example, if mathematics results are below 60 percent. The target are the schools that are within the district we go there and help those schools. My duties as a mathematics coordinator of team teaching, I am the one who is responsible to organise teachers, learners, and the venue.

3.7 Profile of the participants who responded to the questionnaires

There were 11 participants who responded to the questionnaires. The participants were from the Siyakhula circuit (pseudonym) in uMgungundlovu district. There were four lead teachers, one cluster secretary and six members of the cluster who responded to the questionnaires. Most of the participants were between 30-39 years and they have the experience of teaching mathematics. The eleven participants are qualified to teach mathematics with nine participants who have B.Ed. degrees; three of the nine participants have B.Ed. Honours degrees; two of 11 participants have a BSC and a PGCE. The teaching experience of the participants differs. There are six participants whose teaching experience ranges between 1-5 years. Four of the 11 participants range between 6-10 years and one of the 11 ranges between 11-20 years. Table 2 below shows the biographical information about the questionnaire participants.

Table 2: Biographical details of the questionnaire respondents from the mathematics cluster

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10	Participant 11
Gender	Female	Female	Male	Female	Male	Male	Female	Female	Male	Male	Female
Age range	30-39	30-39	20-29	30-39	30-39	20-29	30-39	30-39	30-39	30-39	30-39
Teaching experience	11-20 years	11-20 Years	0-5 Years	0-5 Years	0-5 Years	6-10 years	11-20 years	6-10 years	6-10 years	11-20 years	6-10 years
Teaching qualifications	B.Ed.	B.Ed. Hons	B.Ed.; B.Ed. Hons and MED	Bed & B.Ed. Hons	B.Ed. Hons	BSC + PGCE	B.Ed.; B.Ed. Hons and MED	BSc + PGCE	B.Ed.	B.Ed. Hons	BSC + PGCE
Portfolio in mathematic Cluster	Just a member	Just a member	Just a member	Lead teacher	Just a member	Lead Teacher	Secretary	Lead teacher	Just a member	Lead teacher	Just a member
Duration of membership in a cluster	1-5 years	11-20 years	1-5 years	1-5 years	1-5 years	1-5 years	6-10 Years	1-5 years	6-10 years	6-10 years	6-10 years
Grades taught	8;10;11&12	10;11 &12	8; 10 & 12	9; 10 & 12	8; 10 & 11	10; 11 &12	10,11 and 12	9; 10 & 12	10; 11 & 12	10; 11 & 12	10; 11 & 12

The questionnaire was used to find the viewpoint of all mathematics cluster teachers in Siyakhula circuit (pseudonyms). The questionnaire was conducted during the national lock down of Covid-19 which started on the 26th of March 2019. All the members of the mathematics cluster were given the questionnaires to answer except the ones that were invited for interviews. Those who agreed to be interviewed were not willing to complete the questionnaires. There were 22 members of the mathematics cluster including the subject advisor. I targeted 18 participants, but only eleven were returned. There were 6 females and 5 males' respondents.

3.8 Data Collection methods

The three data generation methods used in this study were semi-structured interviews questionnaires and documents analysis.

3.8.1 Interviews

The study adopted semi-structured interviews. According to Cohen et al. (2011), research interviews is a dialogue between the interviewer and the informant and is initiated by the interviewer. Similarly, an interview "is a survey that is administered verbally, either individually or in groups" (Laurer, 2006, p.37). According to Gill, Stewart, Treasure and Chadwick (2008) the purpose of research interviews is to explore the views, experiences, beliefs and/or motivations of individuals on specific matters. Cohen, Manion and Morrison (2018) also contend that the interview purpose is to 'understand and assess' a person's situation and to gather the information to assist in research objectives (p.508). For the purpose of this study the interviews were used to generate deep understanding about teacher learning in a mathematics cluster.

Brenner (2006); Gill, Stewart, Treasure, and Chadwick (2008) classify interviews into three categories namely, "structured interviews, unstructured interviews and semi-structured interviews" (p.362). Structured interviews are well-defined as planned questions whereby the interviewer asked a list of predetermined questions and does not probe (Gill, Stewart, Treasure & Chadwick, 2008) whereas unstructured interviews are defined as flexible interviews because "it is limited by a set of predetermined questions" (Brenner, 2006, p.362). Semi-structured interviews differ from structured interviews because in semi-structured interviews the researcher has the freedom in questioning and probing responses (Gill, Stewart, Treasure & Chadwick, 2008).

This study adopted semi-structured interviews because they are commonly used in a qualitative research study (McMillan & Schumacher, 2006). Using the semi-structured interviews in this study was based on the fact that as the researcher I was able to inquire for more information about teacher learning in a mathematics cluster. I was also able to do some follow up questions and probe the participants further (Cohen, et al. 2011). This is supported by Brenner (2006) who claims that interviews allow the researcher to access participants' experiences, interpretations and how they observe the world. Likewise, semi-structured interviews were ideal for the reason that the exploratory nature of learning was allowed.

As a researcher I planned everything with the participants since the interviews was conducted in different places. The participants were given the freedom to choose a convenient venue for the interviews. This was done to make sure that participants were comfortable during interviews. In the same vein, Robinson (2009) states that the environment needs to be friendlier and relaxed in the semi-structured interviews. I conducted the interviews during the lockdown level 3 and I followed all the rules and protocols that was set by the President and Department of Health. I wore a mask as well as a face shield mask and I wore gloves for my hands. I also carried sanitizer in case it was needed.

Semi-structured interviews frequently use open-ended questions (McMillan & Schumacher, 2006). This corresponds with this study as open-ended questions were used. This allows the participants to be flexible and provide in-depth responses to the questions (Opie, 2004). Additionally, through the use of semi-structured interviews, my participants had an opportunity to open up. The semi-structured interviews were conducted individually and took 45 minutes to be completed. In addition, Gill, Stewart, Treasure and Chadwick (2008) state that "all interviews should be tape recorded and transcribed verbatim afterwards, as this protects against bias and provides a permanent record of what was and was not said" (p.293). Furthermore, the audio recorder was used during the interviews to ensure that valuable data was not missed because the researcher could not write everything said by the participants during the interviews. I transcribed interviews with the purpose of data interpretation. Subsequently, the WhatsApp voice note was used for follow-up interviews to ask for explanations on responses that was unclear to the researcher.

The advantages of semi-structured interviews as a data generation method were that interviews were flexible, and data could be checked easily for accuracy. This in line with Gill, Stewart, Treasure and Chadwick (2008, p.291) who pointed out that "semi-structured interviews consist of several key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge in order to pursue an idea or response in more detail". The interviews were arranged for a suitable time. During the interviews, the researcher had a chance to understand participants' views, perceptions, and opinions. Moreover, face-to-face interviews assisted me to ask personal information, control in questioning and probing (Creswell, 2009). The participants had the freedom to elaborate on information that they felt was important to the researcher. Any misinterpretations or misunderstanding were corrected easily because the interviewer and respondent were physically present. In addition, a global understanding of participants was obtained during the semi-structured interviews. In addition, the interviews allow the researcher to observe body language and a personal connection was developed. Using semi-structured interviews assisted in collecting important information.

However, the interviews had limitations as some of my participants were nervous before the interviews started therefore, the participants did not answer some questions honestly during the interviews (Brenner, 2006). Other participants did not feel free to respond to some questions because of the presence of the researcher. Gill, Stewart, Treasure and Chadwick (2008) stated that semi-structured interviews sometimes last for hours which makes them time consuming and can be difficult for participants. Planning for the interviews, recording interviews and interpretation of responses need much time. Additionally, conducting the interviews required a researcher to use cash for travelling into different places since the interviews was not conducted on the same day. It can be difficult to determine the authenticity of what participants shared (Brenner, 2006).

Interviews had some disadvantages because of the Covid-19 pandemic which required the researcher to move up and down as face-to-face interviews were not allowed. Conducting interviews during lock down level three was not easy because the participants and the researcher had to wear a mask and observe a social distance of 1, 5 meters. I had to put a voice recorder next to the participants so that everything they said was recorded.

3.8.2 Questionnaires

In this study I also used questionnaires. At first, I planned to use a cluster observation because due to Covid-19, all cluster workshops were adjourned. Since the data was collected during level 5 of lockdown where observations were not allowed, I had to use questionnaires as a data collection tool to obtain the views of all cluster members and questionnaires were more accessible for all the participants. I was able to deliver the questionnaires and collect them.

Cohen, Manion and Morrison (2018) stated that there are structured, unstructured, and semi-structured questionnaires. Structured questionnaires are used when the sample size is larger and closed questions are then used (Cohen, et al., 2018). Whereas unstructured questionnaires are used when the sample size is smaller the questions are more open-ended (Cohen, et al., 2018). Lastly, semi-structured questionnaires use both open-ended and closed ended questions. Similarly, this study adopted the semi structured questionnaires because the respondent was given a questionnaire that had both closed and open questions.

The open-ended questions were used in this study to find out how teachers learn, the knowledge they acquire and to find out whether the mathematics cluster adheres to the characteristics of PLCs. The open-ended questions allow the participants to write as they wish (Cohen, et al., 2007). Close ended questions were used for the biographical information of the participants.

Semi-structured questionnaires had an advantages because my sample size was small, so I was able to collect the information and present it. Questionnaires was easy to distribute using email and WhatsApp. Other advantages were that it had a total of sixteen questions, seven formed by closed questions and nine were open ended questions, so the participants had the opportunity to choose and write freely as well. The closed ended questions were more about biographical information, and it was easier to analyse (Cohen, et al., 2018). The open-ended questions offered more detailed information about the knowledge that mathematics teachers learn, and the extent the mathematics cluster reflects the features of a professional learning community.

On the other hand, there were limitations for using questionnaires in this study. Firstly, using questionnaire was not my first choice but because of Covid-19 cluster workshops were suspended so it forced me to change my data collection methods. I had to remove the cluster observation and prepare the questionnaire tool. The questionnaire was prepared extremely late, and I had to ask the participants to sign the consent form and answer the questionnaire. The open-ended questions took

a lot of time and were not easy to code because the data collected was larger (Cohen, et al., 2007). There were many responses, so it was difficult to make comparisons.

3.8.3 Document Analysis

Document analysis is a logical process for reviewing both manual and computer-based documents (Bowen, 2009). Bowen (2009) further stated that document analysis is used mostly by scholars in qualitative research where researchers analyse and interpret the information and also highlights the assessment focus. The documents I analysed include cluster worksheets, policy document about clusters from the Department of Education, minutes of a cluster meeting, communiques established by the subject advisor and documents distributed in workshops. Cohen et al. (2007) highlight that the use of document analysis could assist the researcher to reach inaccessible facts that could not be exposed in the interviews. Through document analyses I was able to cross-validate data from interviews and questionnaires. Another strength of document analysis is that documents are stable and are suitable for repeat reviews (Bowen, 2009). Analysing documents is easy because documents have not changed and can be read and reviewed several time and cannot be influenced by the researcher (Bowen, 2009). Document analysis in this study saved time and any transcription expenses. This is in line with Bowen (2009) who stated that analysing document saves time and is more cost effective than conducting interviews.

However, document analysis had some limitations. Bowen (2009) stated that documents cannot provide necessary information needed by the researcher to answer the research questions. Some documents provide less valuable information or at times, not at all. Furthermore, some documents that I have analysed contained inadequate data or unreliable information. This is supported by Bowen (2009) who argued that other documents have gaps that lead the researcher to search more and find additional documents than planned (Bowen, 2009). Bowen (2009) contends that "documents can contain data that are no longer being recalled, contains information that are forgotten by the participants, changes and development can be tracked" (Bowen, 2009, p.57). Additionally, some documents that I intended to analyse were not easily found or accessible for example, the policy document about clusters from the department. Using document analysis to generate data was a bit challenging because the documents were sometimes difficult to retrieve information from or consciously blocked. Bowen (2009) observed that documents and the researcher have the potential for bias.

3.9 Research Context

Detailed information about the context of this study was provided in Chapter One. The uMgungundlovu district upon which Siyakhula (pseudonym) mathematics cluster is located has 16 circuits; each circuit consists of 12-15 schools. Siyakhula mathematics cluster is in one of the 16 circuits and mathematics teachers from Siyakhula cluster are from one district. The schools under the Siyakhula mathematics cluster are located in semi-urban areas. The attendance registers of the moderation meeting held on the 18th of October 2019 indicates that the Siyakhula mathematics cluster has 22 teachers from 12 high schools.

Siyakhula mathematics cluster was organised by the Department of Education. Jita and Mokhele (2012, p.1) stated that "many provincial education departments in South Africa have sought to institutionalize and encourage the formation of teacher clusters as a vehicle for the continuing professional development of teachers. They further add that teacher clusters are formed to bring teacher professional development closer to the classroom. Jita and Mokhele (2013) described that teacher clusters were formed with the aim of improving teachers' classroom practices and learner performances. The attendance registers of the workshops also show that there are three non-governmental organisations (NGOs) that are involved in this cluster. For confidentiality reasons I have decided to give these NGOs pseudonyms; EXM1; EMX2 and EMX3.The mathematics teachers attend workshops organised by the DBE and the NGOs. The teachers in this cluster attends the workshops called Just in Time, for the schools that obtained below 60% in the grade 12 National Senior Certificate (NSC) results (DBE provincial circular). The NGO's workshops are held in three ex Model C schools within the district. The Model C Schools existed before the democratic elections in 1994. These schools were not open for all races and was a school for 'white only'. After the democratic elections, Model C schools became multiracial schools. The NGO's and the DBE uses these ex-model C schools as a venue for meetings and workshops of Siyakhula mathematics cluster.

Siyakhula mathematics cluster is led by the subject advisor and teachers who are occupying different portfolios such as cluster coordinator, secretary, and lead teachers. The Siyakhula mathematics cluster has five lead teachers who were selected because of their performances and consistent results in teaching mathematics in Grade 12. The teachers' portfolios in Siyakhula mathematics clusters are shown on the profile of the participants.

3.10 Data Analysis

Boeije (2010, p.76) explained that "data analysis in qualitative studies refers to the process of breaking up or segmenting the data into parts and reassembling the parts into a coherent whole". Data analysis "allows for the creation of thick descriptions, theme identification, generation of explanations and action apparent in the case" (Rule & John, 2011, p.77). The purpose of data analysis in this study was to determine themes, patterns, concepts and meanings from the participants' responses. I used thematic analysis to make sense of data (Cohen et al., 2007). Thematic analysis is described as a method of coding, summarising and organising qualitative data into themes, groups and clusters (Wellington, 2015). The study's findings were presented, organised, analysed and explained and finding meaning with what was described by participants. I transcribed all audio typed interviews into written transcripts and used a Microsoft document. Following, was reading the interviews transcripts for several times with the intention of coding. The participants were also given a chance to read the collected data from them for verification purposes. Cohen et al. (2007, p.480) states that "a code is a word or abbreviation sufficiently close to that which it is describing for the researcher to see at a glance what it means".

Bertram and Christiansen (2014) state that deductive analysis is when the researcher uses the concepts of a theory. I analysed data from the semi structured interviews, questionnaires and document analysis using the conceptual frameworks. The elements of designing professional development that works (Birman, Desimone, Porter& Garet, 1999), domains of mathematics knowledge (Ball, Thames, & Phelps, 2008) and features of PLCs (Stoll, Bolam, McMahon, Wallance & Thomas, 2006) were used to analyse data. Consequently, the deductive analysis was useful for this study. The discussion findings were thus provided according to the research questions.

3.11 Trustworthiness

According to Lincoln and Guba (1985), "trustworthiness allows the researcher to persuade its readers that the findings of the study are worth paying attention to and taking account of" (p. 290). Trustworthiness of the qualitative is ensured by abiding by the four principles suggested by Lincoln and Guba (1985) which are "credibility, transferability, dependability and confirmability"(p.290).

Credibility signifies that the study has documented the correct essence of the case study (Lincoln & Guba, 1985). Petty, Thomson, and Stew (2012) proclaimed that credibility is the process where participants trusted the findings from the study. In this study credibility was ensured by engaging in member checking, transcripts were given to the participants to read and validate the accurateness of the data. Padgett (2008) adds that credibility might be achieved if the bias would be reduced. I used a peer reader to scrutinise and offer a different viewpoint and checked whether data was interpreted correctly. This study used different data generation methods to achieve triangulation which strengthens the credibility of the research. The credibility was enhanced by using the audiotape to record observations done in a cluster and semi-structured interviews. The audiotape was used to record the interviews.

Transferability occurs when the researcher can show that the case is related with other similar cases (Rule & John, 2011). Transferability also refers to the appropriateness of the findings. Furthermore, Devers (1999) states that if the context is similar findings could achieve transferability. The researcher's role is to identify the main aspects of the context from which the findings developed. Moreover, the findings in qualitative research cannot be generalised and transferred (Lincoln & Guba, 1985).

Dependability refers to the steadiness of data over a period of time (Bassey, 1999). It was not always easy to achieve dependability in this qualitative study however, dependability was ensured by making sure that data obtained in the interviews was substantiated with data obtained from the questionnaires and document analysis. The participants were informed of the process of the study, the research design and the data collection methods. Thus, the credibility and trustworthiness would be ensured.

Elo, et al. (2014, p.2) described confirmability as "the potential for congruence between two or more independent people about the data accuracy". Confirmability refers to the potential of addressing concerns about the researcher's influences and biases of the study (Lincoln & Guba, 1985). I was aware of my subjectivity because I am a member of mathematics cluster and teach grades 10-12. I ensured that the data will be kept in a safe place in my supervisor's office, at the School of Education for five years, and thereafter be destroyed.

3.12 Ethical Considerations

Cohen et al. (2007) described "ethics as a matter of principled sensitivity to the rights of others, and that, while truth is good, respect for human dignity is better" (p.57). As a researcher I adhered to the ethical and moral dimensions because the study is within a social science context. Creswell (2012) explained that when conducting research, it is very important to address ethical issues. The Department of Basic Education of KwaZulu-Natal issued a gatekeeper's approval letter (Appendix A) and the University of KwaZulu-Natal Research and Ethics Committee granted the study ethical approval to proceed with research (Appendix B). In addition, I was granted permission to observe the mathematics cluster from the mathematics subject advisor (Appendix C). I informed the mathematics subject advisor about my study that focused on teacher learning in a mathematics cluster as a PLC. I also obtained a consent from the subject advisor as one of my participants (Appendix D). I provided the subject's advisor with the information on the data collection methods. All the participants signed the informed consent and the confidentiality clause (AppendixE). In the participants' consent letter, it was described that the audiotape or voice recording for data collection was to be used. However, all participants agreed to be interviewed and voice recorded concurrently. The informed consent letters clearly stated that the participation in the research is voluntary, and the participants can withdraw at any time with no repercussions. This issupported by Baxter and Jack (2008) who declared that "participation should at all times be voluntary and no one should be forced to participate in a project" (p.549). Participants was guaranteed confidentiality and pseudonyms were used. The participants preferred being interviewed after school in their own space, but the subject advisor was interviewed in his office.I transcribed data after the interviews.

Furthermore, Creswell (2012) declared that "the information on participants should be regarded as confidential unless otherwise agreed on through informed consent (p.195)". I used pseudonyms for participants' anonymity and the data remained confidential. I am responsible for the information given by participants. The data is kept on my laptop and will only be seen by my supervisor. This study was completed in 2021, the integrity of the participants was assured and protected. The purpose and nature of the study, the data collection methods and the time frame were explained to participants to ensure that they were comfortable with the methods. The dates for interviews were set with the participants. The interview schedule, the questionnaires, voice

recordings, informed consent letters and all data from participants was locked in filing cabinet. The transcribed data will be locked in the School of Education, Pietermaritzburg campus (Room 47) filing cabinet for five years. The study findings will be shared with the Department of Basic Education and the University of KwaZulu-Natal.

3.13 My Role as A Researcher

My role as a researcher was to explore how mathematics teachers learn in a cluster. Additionally, it was my responsibility to select the appropriate research approach, research design and paradigm, which best suits the study. My role was also to find the type of case study and relate it to my study. The researcher's role was to collect data using all three data generation methods which were interviews, questionnaires, and document analysis. I analysed data using thematic analysis and drew conclusions from the findings of the study. I am a member of the Siyakhula cluster (pseudonym) and teach grades 10-12 mathematics. I tried to be objective and not to influence the results of the study since I teach these grades. The role of a researcher was to understand how teacher learn in a mathematics cluster. My main role as a researcher was to adhere to all ethical principles and ensure that the study should not cause pain to anyone.

3.14 Conclusion

To end this chapter, I discussed the methodology and the research design. I also discussed the research paradigm that underpinned the study. The different methods of data generation such as semi-structured interviews, unstructured observations and document analysis were explained. In addition, the sampling procedure regarding the selection of participants and data analysis was discussed. The chapter has shown how the trustworthiness and ethical considerations were established. My role and the limitations of this study were presented. The next chapter presents the research data.

CHAPTER FOUR
DATA PRESENTATION AND ANALYSIS

4.1 Introduction

The previous chapter presented the research design and the methodology of the study used to generate data. This chapter presents, describes and analyses the data through the conceptual frameworks of Birman et al. (1999); Ball et al. (2008) mathematics teacher knowledge and Stoll,et al. (2006) characteristics of a professional learning community (PLC). The data in this study was generated through the semi-structured interviews, document analysis and questionnaires. The research study focused on grade 10-12 mathematics teachers in the Siyakhula cluster exploring how these teachers learn and the types of knowledge as well as the extent the mathematics cluster adheres to the features of a professional learning community. This chapter also includes the profile of participants.

4.2 Presentation of Data and Analysis

In this section I present the data using Birman, et al. (1999); Ball, et al. (2008) and characteristics of PLCs (Stoll, et al. 2006).

4.2.1 Birman, et al. (1999) features of professional development

Birman, et al. (1999) features of professional development that I used to analyse the data are form, duration, participation, content focus, active learning and coherence. These elements help me to understand how teacher learning occurred in the Siyakhula mathematics cluster.

4.2.1.1 Form

Birman, et al. (1999) define form as an activity associated with traditional workshops or teacher networks. Form refers to the structure where teachers develop each other by networking with other teachers and learn jointly as a group. There are five forms of professional development that emerged from the data generated through semi-structured interviews, questionnaires and documents analysis: DBE workshops, NGO's workshops, WhatsApp's group discussions, team teaching and sharing experiences and resources.

4.2.1.2 DBE workshops

Three of four participants that were interviewed reported that they attended workshops organised by the DBE. These workshops are usually run by the subject advisors and facilitated by the lead teachers. For example, Neleh explained:

> *In the beginning of the year, I attended the orientation workshop where the subject advisor gives the analysis of Grade 12 mathematics results per school. We also look at the question paper for the previous year and analyse it. I identify the fair and unfair questions to learners and check questions that learners made more errors on.*

Nine of the eleven participants who responded to the questionnaires concur with the above statement with participant 9 saying:

> *I have attended the orientation workshops where the subject advisor explains the moderation process, show how to give constancy, accuracy and accuracy mark. In this workshop we select the cluster coordinator and secretary. We looked at the activities of the term and discuss how we can improve the cluster results.*

Participant 3 from the questionnaire commented on the workshops organised by the Department of Basic Education in this manner:

> *In the orientation workshops, I have learnt the new knowledge of teaching mathematics more especially in grade 12. I also attended the Just in Time workshops that equip teachers with necessary skills to teach mathematics.*

The attendance registers of the orientation workshop conducted by Khenani (mathematics subject advisor) on the 6$^{th\ of}$ February 2020 also indicates that the Siyakhula mathematics teachers had attended the orientation workshops. The findings seem to confirm that mathematics teachers do attend cluster workshop organized by the DBE.

4.2.1.3 The Non-Governmental Organisations (NGOs) workshops

The interview data suggests that the mathematics teachers are also attending workshops organised by Non-Governmental Organisations. Tholah responded when she was asked about how often they meet as a mathematics cluster. This is what she says:

Last year I attended about six workshops organised by the NGO's that took place in different places. I attended the EMX2 workshops three times a year and also EMX1 three times.

Additionally, one questionnaire participant stated that there are NGO workshops run by the EMX1 facilitator. He reported that these workshops take place in one of the ex-model C schools. Participant 1 explains:

There were many workshops I have attended since I started teaching but there is this workshop, we attended at EXM1.

Participant 6 explains about how the EXM3 workshop developed his confidence:

The workshop that developed my confidence in teaching Probability and Functions (graphs) is the EMX3 workshop which, I have attended 1n 2015 for three months. The EMX3 facilitator demonstrated how to teach using the mathematics model.

When probing about the three months workshop the participants elaborated:

I was release from teaching in my school for three months to attend the EMX3 workshops. We started in January 2015 and ended in March 2015; I had been away for the whole term. They were a replacement in order for me to attend the EXM3 workshop.

Participant 10 responded to the question; "how many workshops have you attended since you joined the mathematics cluster?"

I have attended workshop organised by the EMX3 NGO's in 2017. I started in April and completed in June. The EXM3 workshop was much organised in terms of the venue, the program, and the facilitator. Now I am an expert in most of the mathematic soft wares.

Participant 8 also highlighted the workshop run by EMX3 and said:

I attended the project called EXM3 workshop where I learnt how to use a computer to teach geometry, probability, and other chapters. These workshops developed the confidence.

The findings indicate that there are other workshops that are organised by retired mathematics teachers called EMX2. Tholah talked about how often she had attended the workshop:

Yes, there is a learning programmes in this cluster. I attended the workshops organised by the retired teachers at EXM2.

This confirms what was mentioned by participant 9 when he was reporting about the workshop he attended:

It occurred in the past two years in EMX2, where we had mathematics workshop. The facilitator was an old lady who was a mathematics specialist in the province. The programme was highly accredited by DBE and NGO's.

In summary, mathematics teachers in Siyakhula cluster seem to suggest that teachers attend the DBE and NGO workshops as professional development activities.

4.2.1.4 WhatsApp groups discussions

The participants that responded to the questionnaire explained that they use a WhatsApp group as a platform for learning mathematics where they help one another by sharing teaching material and methods of solving mathematics problems. For example, participant 10 explained that:

By using WhatsApp group, when someone posted the problem, we do it and send it back. On WhatsApp, teachers send documents, tests, memorandum, worksheets, assignments, projects and so on.

Agreeing with participant 10, Tholah commented:

[w]e share questions via WhatsApp in this mathematics cluster. We also meet in WhatsApp group with teachers, I also have those multimedia chat where we discuss some important concepts for example if there is something that I don't understand I just write and post it to my fellow colleagues, and we discuss it and I ended up gaining different strategies and views.

The WhatsApp group is a platform for sharing ideas, resources, and challenging problems.

4.2.1.5 Team teaching as a professional development activity

The data from semi-structure interviews and questionnaires revealed that teachers from Siyakhula feel that the mathematics cluster promotes team teaching. Participant 1 explained how mathematic teachers work in the cluster workshops:

As mathematics teacher, we work as a team to make sure that all teachers in this cluster benefit from being a member. We plan together, work together, and teach planned lesson. The team teaching and sharing of resources is always encouraged by our subject advisor.

In the same way, participant 8 said:

We normally ask one another to come and assist at your school in teaching certain topics. Also lead teachers assist specifically in Grade 12 syllabus.

Khenani the subject advisor seems to confirm the team teaching among the mathematics teachers by saying:

Through individual discussions then arrangement made school visitations. Teamwork is the best weapon in this cluster for acquiring of skills and knowledge. Teachers with experience demonstrate how to teach a certain topic. Team teaching is helpful even in the dissemination of information.

These interview and questionnaire extracts seem to indicate that team teaching takes place in the Siyakhula mathematics cluster. Team teaching helps mathematics teachers with teaching particular topics.

4.2.1.6 Sharing of experiences and resources

The data from questionnaires and semi-structured interviews revealed that teachers in the mathematics cluster learn by sharing resources and experiences. Participant 2 described:

In these workshops we share teaching methods and strategies that we use in our different schools. We share material that our learners benefit from using them. So, meeting in a cluster is helpful.

Correspondingly, participant 3 mentioned that:

In this cluster, we share information, networking and to develop one another in mathematics content.

In the same way, during the semi-structured interviews sessions, Phumzile outlined that teachers share previous examination papers, share knowledge and skills in order to improve their teaching practice:

> *Usually, we share all the required resources, we share old exam papers, share our experiences, it is just sharing, improving, and empowering ourselves. Teachers exchange ideas for example when I know that miss so and so is good at probability then I will ask that teacher comes may be on a Saturday to help my learners. We do a lot of sharing, interchange, all that stuff.*

Additionally, Neleh supported this statement by saying that:

> *We also empower each other in the subject we teach by running workshops. In those workshops we share teaching methods and strategies that we use in our different schools.*

These statements above seem to suggest that mathematics teachers in Siyakhula (pseudonym) cluster share teaching methods and strategies used by different teachers in their schools. The findings displayed that teachers share all the relevant resources like old exam papers, share experiences, ideas, skills, and knowledge.

4.2.1.7 Duration

Birman, et al. (1999) maintain that the workshops that takes longer time it focuses on a content area and learning becomes active compared to those run over a shorter period of time. The three out of the four participants that were interviewed reported that the DBE workshops took place once per term and also mentioned that moderation workshops start at 9h00 and finishes at 14h30. Khenani reported that they meet every term when he was asked about the duration of professional activities:

> *Every term we meet to moderate for content workshops and other mathematics related issues like if they are queries, setting of papers, cluster papers where need be, School Based Assessment (SBA) training. The moderation workshop took almost five hours and 30 minutes.*

Similarly, eight out of the eleven questionnaire respondents stated that the DBE workshop took place once a term. For example, participant 10 mentioned that:

> *[w]e usually meets once a term to moderate, setting of common papers, discussion with colleagues, setting of tasks for the term and memorandum discussions.*

Tholah describe that:

> *We meet four times a term, first term we usually held an orientation workshop where we meet there and select a cluster coordinator and a secretary. Second meeting is for setting of tasks for the term. Third meeting is the pre-moderation of tasks and the fourth meeting is the post moderation of work administered for term. In the cluster we start by moderating learners and teachers work, followed by the content discussion and lastly, we check chapters that need to be taught.*

The data from the semi-structured interviews and questionnaire indicate that teachers attended the workshops. Phumzile mentioned that:

> *In the EXM2 workshop I attended three times a year and EXM1 six times a term.*

This corresponds with participant 1 from questionnaires who further stated that:

> *[w]e used to go to EXMI workshop every Tuesday twice a month. I thank our subject advisor together with the NGO's for organising such a fruitful workshop I gained a lot.*

Below is a photograph of the extract from the minutes of the workshop organized by EXM3 NGO:

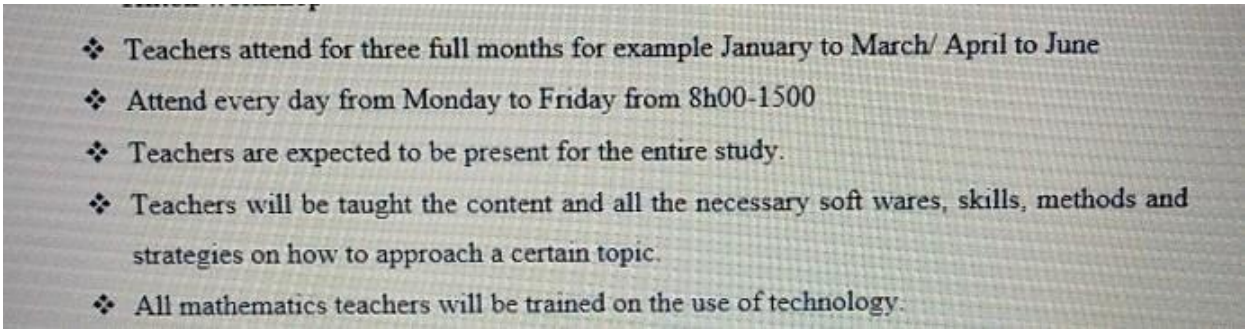


Figure 2: Minutes of the EXM3 workshop meeting of the Siyakhula cluster (minutes are from EXM3 workshop).

Figure 2 shows the duration and focus of the EXM3 workshop. It has been said in the minutes that they are aiming to train all mathematics teachers in computer software. The minutes also revealed that in the EXM3 workshop, teachers participate for a full 3 months. The detailed information about this 3 months' attendance is explained above by participant 6 in the section of Non-Governmental Organisation (NGO's) workshops.

The data findings suggest that the longer they spend on the content focus area the more active learning becomes compared to those within a shorter time. It is revealed that DBE workshops are

run over a shorter period of time while the NGO workshops are usually run over a longer period of time when meeting with teachers.

4.2.1.8 Participation

Teachers learn by participation (Birman, et al., 1999). Birman et al. (1999) explains that participation takes place when teachers from different schools participate cooperatively in their group discussion. Participation focuses on how teachers participate in the activities given and also looks at the nature of involvement in groups. In this study, participation of mathematics teachers during their workshops was not fully understood because I did not get an opportunity to observe what they do in the cluster workshops because of the Covid-19 pandemic and the teachers' workshops were suspended. I relied on what they have said in the semi structured interviews and questionnaires. The generated data from the questionnaires and semi-structured interviews suggests that teachers from the mathematics cluster participate individually and in groups. Phumzile reported about individual participation:

> *In Just in Time workshops, we first learn individually where all teachers get an opportunity to write a pre-test. When we finished writing we then discussed in groups. After all discussions we write a post-test as individuals again.*

Participant 1 explains that they work as a group:

> *We work as a group, and we present information on the board. The facilitator prepared a document full of questions even now I am using those documents and worksheets.*

Furthermore, Neleh mentioned:

> *We do most of the activities in groups such as moderation of learners' scripts, we learn together cooperatively when discussing content, memorandum and doing group presentation.*

The above extracts from interviews and questionnaire data suggests that teachers in the mathematics cluster participate both individual and collaboratively. It is reflected that most of the activities were done jointly, and teachers also share resources and empower each other.

4.2.1.9 Content focus

The data seem to indicate that many activities were done by teachers in different workshops such as subject matter and memorandum discussions, marks allocation, moderation, unpacking the curriculum and learning how to use technology. Participant 1 from the questionnaires stipulated that:

> *We treat many aspects of mathematics, especially Euclidean Geometry, Probability and Finance. Those were problematic chapters to me because I had not done this at the University level.*

Neleh clarified the activities which occurred in the mathematics cluster:

> *We discussed the paper written by learners and finding other methods that are not in the memorandum. So, you are being able to develop yourself and if there are teachers who having problems on the certain topics that was included in the paper that was written you are able to explain it more so that they understanding it better. From these activities we learn how to moderate, allocate marks, you learn other methods to do a certain problem.*

Below are the same views voiced by Phumzile:

> *When we meet for moderation, we discuss challenges that we are facing in our schools with our learners, sometimes challenges of the resources that they are insufficient.*

Participant 3 stated that:

> *In this cluster, I have learned new skills of teaching Euclidean Geometry in grade 11 and 12 and also trigonometry. I have gained the knowledge of marking and moderating learners works accurately.*

Neleh also reported that they have a WhatsApp group where they help one another. However, WhatsApp was not used as a data generation tool in this study. He elaborated by showing one of the WhatsApp discussions with other teachers in the group. Below is an illustration in Figure 3 which shows the content focus in the WhatsApp Group.

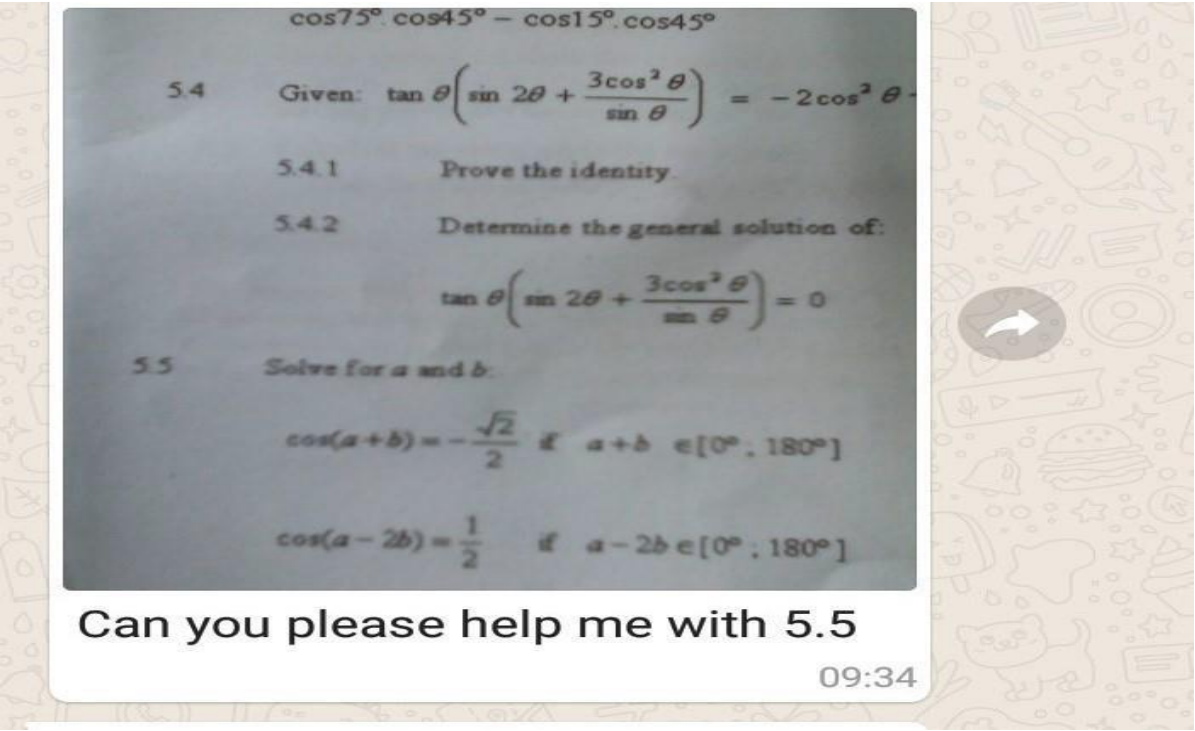


Figure 3: Content focus in the WhatsApp group of Siyakhula mathematics cluster (Neleh'sWhatsApp screen shot on the day of 24 June 2020).

Neleh reported that teachers from the mathematics group responded by writing the solution to this problem asked by one of the teachers in the group.

Below in Figure 4 is an illustration of the response of the question that has been asked above. One of the members of the WhatsApp group responded as follows:

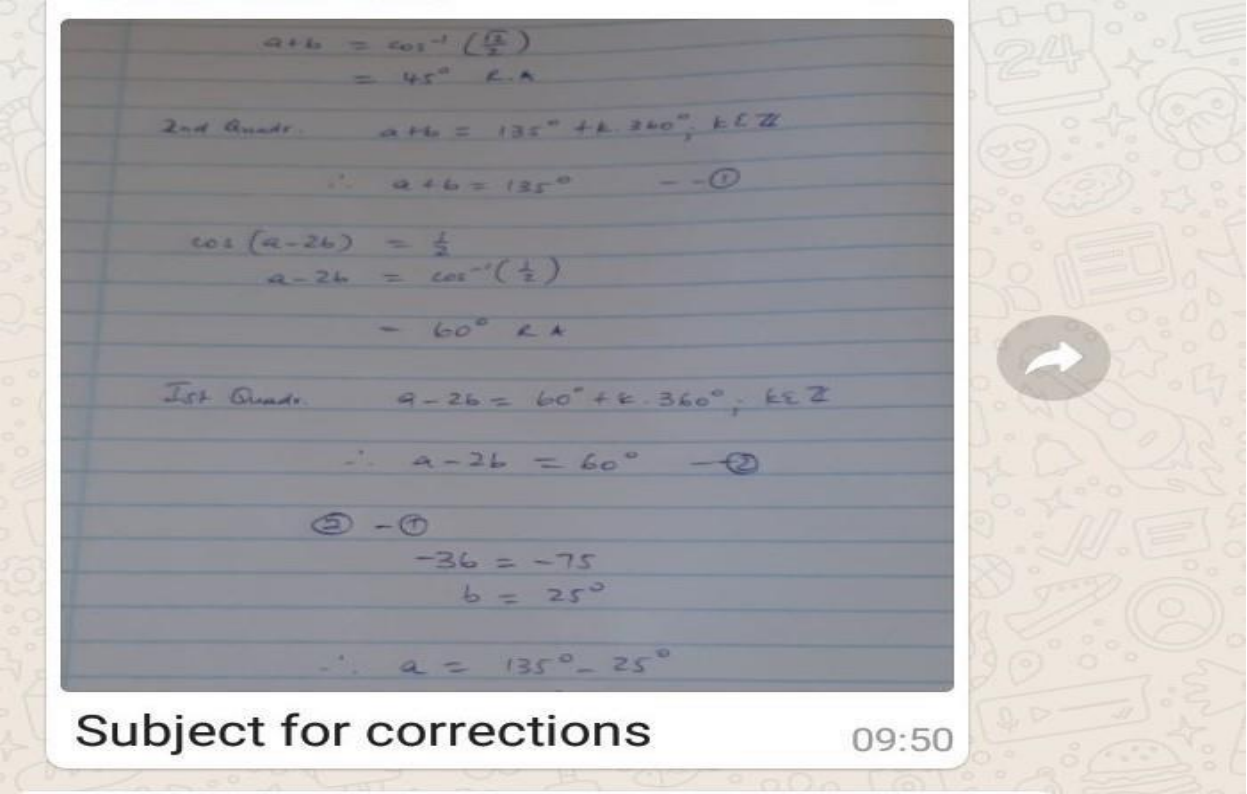


Figure: 4 A response from the question asked in the WhatsApp group (Neleh extracted this fromthe WhatsApp group)

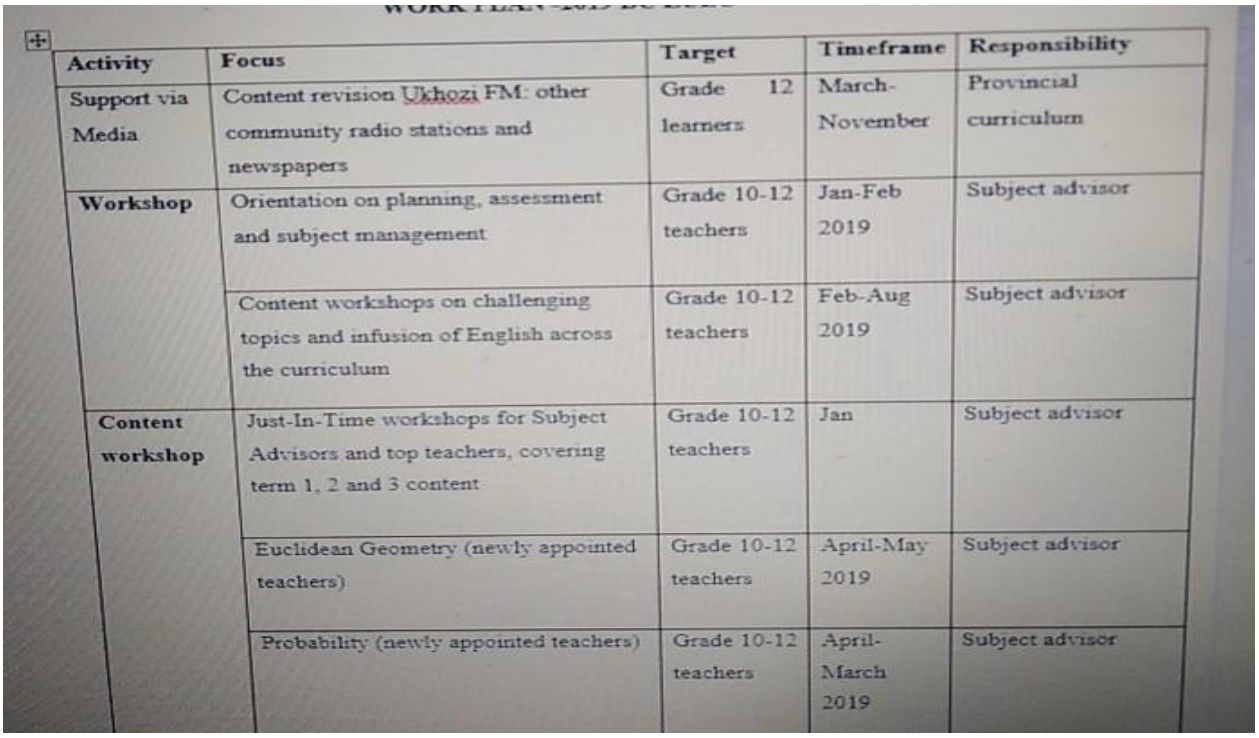
Neleh provided the evidence when he was asked about how they learn in the Siyakhula cluster.

This suggests that members of Siyakhula cluster learn outside of the workshop using WhatsApp as well. They help one another whenever they need help. This shows that teachers assist one other in the content knowledge.

Additionally, participant 1 who responded to the questionnaire said:

> *I have learnt different approaches on how to teach probability, financial mathematics and drawing graphs using a computer. I learned modern methods on how to use the calculator effectively and the importance of using past papers to drill learners for better results.*

Figure 5 below was adapted from subject advisor's Work Plan. Khenani shares the work plan as the document analyses for the cluster.



Activity	Focus	Target	Timeframe	Responsibility
Support via Media	Content revision Ukhozi FM: other community radio stations and newspapers	Grade 12 learners	March-November	Provincial curriculum
Workshop	Orientation on planning, assessment and subject management	Grade 10-12 teachers	Jan-Feb 2019	Subject advisor
	Content workshops on challenging topics and infusion of English across the curriculum	Grade 10-12 teachers	Feb-Aug 2019	Subject advisor
Content workshop	Just-In-Time workshops for Subject Advisors and top teachers, covering term 1, 2 and 3 content	Grade 10-12 teachers	Jan	Subject advisor
	Euclidean Geometry (newly appointed teachers)	Grade 10-12 teachers	April-May 2019	Subject advisor
	Probability (newly appointed teachers)	Grade 10-12 teachers	April-March 2019	Subject advisor

Figure 5: Activities and content focus of DBE workshops in Siyakhula mathematics cluster (The subject advisor's work plan for 2019)

Figure 5 shows the activities planned by the subject advisor, the group targeted, time frame and the person responsible to initiate the workshop. The above figure shows all the workshops and the content workshops organised by the DBE focusing on the knowledge of content and teaching where teachers were taught to teach Euclidean Geometry and Probability. Figure 5 seem to indicate that in these workshops organised by the DBE focused on grades 10-12 mathematics content. Figure 5 also shows that there are workshops that were specifically organised for the newly appointed teachers.

These views above suggested that the professional activities that the mathematics teachers engaged in focus more on mathematics content. The data also revealed that teachers engage in WhatsApp discussions when faced with challenging problems. This is supported by Birman, et al. (1999) who defined that when teachers engaged in professional development activities their content knowledge and skills will increase.

4.2.1.10 The use of technology

Participants have highlighted that in the mathematics cluster workshop teachers engaged in the activities of how to use technology. The participants were taught to search on the internet for previous examination papers and other mathematics articles. Neleh, the participants from semi-structured interviews indicated that teachers use technology in their mathematics classroom. This is what he said:

> *I have an experience that in class you do not have to teach manually every time you can use the technology; you can use a projector that will help you to draw graphs and so on that what I have learnt in my cluster. We were learning how to draw circles on Euclidean geometry using a computer not a free hand. Using technology make the lesson much easy because you waste too much time drawing circles using free hand but if you have drawn them on a computer, it makes you work much easy. So, during your period you are able to teach more.*

Similarly, Phumzile explained how she learnt to use a laptop and a projector to teach mathematics. This is how she responded when she was asked about how they learn in the cluster:

> *The one that I will always carry with me until I retire or even after my retirement is what we got in 2015 where we were chosen as educators by the subject advisor, and we went to EXM3 workshop where we were taught how to teach mathematics using technology and we benefited a lot as mathematics educators because we were taught how to teach using a laptop and a projector. We discovered that almost all the topics can be taught using a technology so that is the most beneficial thing that I ever gained as an educator.*

Furthermore, Tholah also mentioned that:

> *At EXM3 workshop, they taught us how to use technology like computers, projector, mathematics soft wares when teaching mathematics and we were given a series of assignment to write. We learn how to find factors for quadratic equations using acomputer, we did lesson presentations, make mathematics model, we learn how to play mathematics games on a computer we learned many things we also learned human relations.*

Participant 4 described as follows:

> *In these workshops I learnt to use google to search mathematics lessons plans, study material, previous question papers. I learnt how to use a computer to teach geometry, probability, and other chapters. These workshops developed the confidence in teaching mathematics.*

This suggests that teachers learn to use technology for their lessons. Participants stated that teachers draw diagrams using a geometry sketch pad when teaching other subjects. However, participant 5 in the questionnaire data responded by outlining that he has never been trained to use a computer to teach mathematics. Below is what he said:

> *Each and every year, I think from 2014 in every term, subject advisor invite teachers for a computer course of 3 months. Teachers are being taught to teach mathematics using a computer and a projector. Unfortunately, I have never been trained to use a computer I am still using the chalkboard in my lesson but next year subject advisor promised.*

The quotation above seems to suggest that not all teachers have attended the NGO workshop on how to use a computer to teach mathematics. The attendance registers indicate that not all mathematics teachers have attended the same workshops. Some teachers like participant five and participant eleven are still waiting for an invitation from the subject advisor. Mathematics teachers who attended said that now they can teach more problems during one lesson.

4.2.1.11 Active learning

Birman, et al. (1999) highlighted that active learning occurs when teachers are collectively involved in learning activities. The findings from both semi-structured interviews, questionnaires and document analyses seem to suggest that learning in the mathematics cluster occurred through mutual discussions. The extract below highlights the participants' responses to how active learning occurred in the Siyakhula mathematics cluster. During the semi-structured interviews Phumzile said:

> *Most of the time we do calculations as a group, sometimes you will find one of us as teachers do the sums on the board while all other educators are looking at it usually it's a group work. This learning helps the teacher to master new knowledge, it also develops new proficiency which intended to help the teacher to improve student learning.*

Correspondingly, Tholah, described learning as the:

> *From these activities I learn how to draw circle, angles, diagrams, drawing tree diagram, Venn diagram using geometry sketch pad. We are helping each other, and I also learn from my colleagues. I learned new techniques when doing group presentations and I use those techniques in my teaching.*

The responses depict that teachers learn collaboratively in the mathematics cluster. Collaborative learning also came out from the questionnaire responses, for example participant 9 asserted that:

> *We learned as a group how to mark giving an accuracy and constant accuracy marks and I learn to moderate teachers' work.*

However, participant 5 from questionnaire outlined that:

> *In moderation session teachers work as individuals where they moderate learners' scripts. As individual and sign teacher's file. Mathematics teachers help each other whenever you need help*.

The above excerpts seem to indicate that the cluster teachers are involved in collaborative activities which include group calculations, discussing accuracy/constant marks and group presentations. On the other hand, there are individual activities such as moderation of teachers' and learners work and signing the files.

4.2.1.12 Coherence

Coherence of professional development activities is associated with better teacher learning and improved classroom practice (Birman, et al. 1999). I did not observe the mathematics teacher cluster to examine if their classroom practices improved because of the pandemic Covid-19. I relied on what the participants had shared. Participants had different views about the link between the activities they learn in Siyakhula cluster and their classroom practice. Phumzile described it as:

> *[A]t the same time my learners benefited a lot. They know how to connect a projector, they know where to touch, they know how to use a computer. As much as we benefited from that programme as educators, our learners they also benefited.*

In the same way, Tholah noted:

> *It is especially useful because our results are improving each year. It is useful because in theseworkshops we have been taught how to use technology to teach our learners and we learned new techniques. These skills I then used in my mathematics classroom. Using a laptop in my teaching, makes me finish my work before time and get more time to revise work with my learners.*

Participant 11 highlighted that:

> *What I learn in the cluster workshops is transferred to my learners. My learners benefited many skills because in my lesson I use different strategies when explaining problematic sums.*

This is supported by participant 8:

> *When teaching 3D's and 2D's problems I used the models we built at EXM3 workshops where we were taught to use model in order for the lesson to be more understandable. The worksheets we got has some good examples which I used for my learners.*

The extracts also seem to indicate that teachers are transferring skills, information and knowledge obtained in the workshops of the cluster to their classrooms. Teachers reported that they use different strategies and model their teaching practices in order to improve student learning. The mathematics teacher knowledge is discussed in the next section.

4.3 Mathematics Teacher Knowledge

In this section, I used Ball, Thames, and Phelps's (2008) four domains of mathematical knowledge to describe the types of knowledge teachers learn in the Siyakhula cluster. I organised this section by using these four domains of mathematics teacher knowledge namely, Common Content Knowledge, Specialised Content Knowledge, Knowledge of Content and Students Knowledge of Content and Teaching, Knowledge of Content and Curriculum (Horizon).

4.3.1 The Common Content Knowledge (CCK)

According to Ball, et al. (2008, p. 399) the Common Content Knowledge (CCK) is defined as the mathematical knowledge and skills used in a settings other than teaching. This knowledge is vital and required to be used with common sense. It emerged from data that teachers learnt CCK in the Siyakhula (pseudonym) cluster. Participant 6 explains what he has learned:

> *[I] learnt to choose the correct formula when dealing with financial mathematics for example, final lesser payments, outstanding balance, present value, future value, effective and nominal interest. The facilitator made it sure that we all understand and choose correct formulas.*

Phumzile also said:

> *I noticed that calculation errors in class, stuck when solving problems, misinterpretation of terms has been reduced ever since I joined this mathematics cluster.*

These quotes seem to indicate that participants have learnt Common Content Knowledge (CCK) in the Siyakhula mathematics cluster. Their utterances seem to be in line with Ball, et al. (2008) who stated that teachers must have the skills of choosing the correct notation and be able to identify the wrong answers.

4.3.2 Specialised Content Knowledge (SCK)

This knowledge includes "finding an example, analogy, demonstration and resources to make a specific mathematical point (Hill, Schilling & Ball 2004, p.17). According to Ball, et al. (2008) specialised content knowledge is specifically needed for teaching and teachers need unique mathematical reasoning and understanding. The data from semi-structured interviews and questionnaires suggest that teachers learnt specialised knowledge through demonstrations for teaching mathematics. Neleh, explained:

> *The resources used was laptops, scissor, paper, pencil whiteboard, white board makers, projectors and was provided by EXM3. We proved theorems using cutting and pasting. The facilitator used protector to measure angles on paper and then cut the papers, the corresponding angles equal and sides in proportion.*

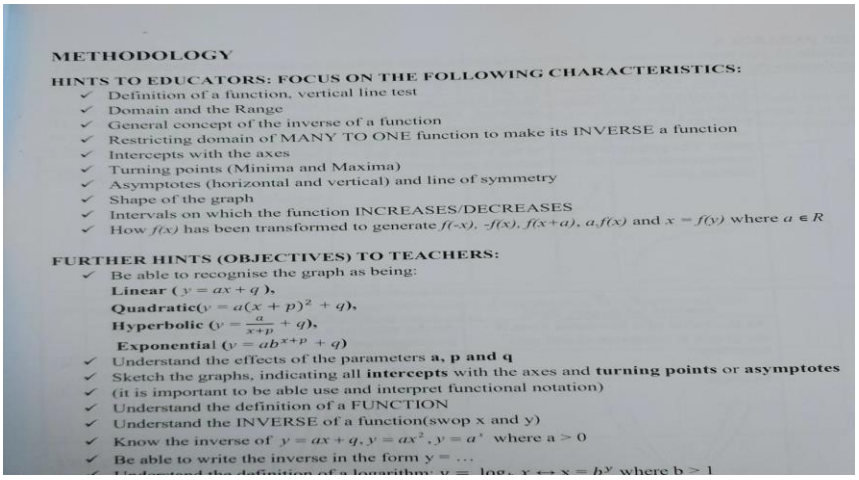
Likewise, Phumzile added:

> *She demonstrated how we can introduce 2D's and 3D's problems. The facilitator used wires to make triangles, cuboid, rectangular prism and cylinder so we were encouraged as teachers to teach using these models. We benefited a lot as mathematics educators because we were taught how to teach using a computer, we discovered that almost all thetopics can be taught using a technology.*

This corresponds with participant 9 who stated that:

> *In the EXM2 workshops, I learnt so many things. The facilitator demonstrated the knowledge of teaching theorems starting by measuring angles and record them. And then later she wanted us to analyse the relationship and give reasoning. We ended by proving the theorems, which I found it easy and I understood the theorems.*

The data findings seem to reveal that mathematics teachers learnt the Specialised Content Knowledge because the facilitator demonstrated the knowledge that is needed for teaching. These responses correlate with the data obtained from the handouts that were issued during the workshop (Just In Time). These handouts show that teachers learned the *Special Content Knowledge (SCK)* in mathematics. The subject advisor gave me this document (Figure 6) for the cluster to be analysed. This document was developed by the subject advisor to help teachers who have students who underperform (got below 60%) in the subject.



METHODOLOGY

HINTS TO EDUCATORS: FOCUS ON THE FOLLOWING CHARACTERISTICS:

- ✓ Definition of a function, vertical line test
- ✓ Domain and the Range
- ✓ General concept of the inverse of a function
- ✓ Restricting domain of MANY TO ONE function to make its INVERSE a function
- ✓ Intercepts with the axes
- ✓ Turning points (Minima and Maxima)
- ✓ Asymptotes (horizontal and vertical) and line of symmetry
- ✓ Shape of the graph
- ✓ Intervals on which the function INCREASES/DECREASES
- ✓ How $f(x)$ has been transformed to generate $f(-x)$, $-f(x)$, $f(x+a)$, $a.f(x)$ and $x = f(y)$ where $a \in R$

FURTHER HINTS (OBJECTIVES) TO TEACHERS:

- ✓ Be able to recognise the graph as being:
  Linear ($y = ax + q$),
  Quadratic($y = a(x + p)^2 + q$),
  Hyperbolic ($y = \frac{a}{x+p} + q$),
  Exponential ($y = ab^{x+p} + q$)
- ✓ Understand the effects of the parameters **a, p and q**
- ✓ Sketch the graphs, indicating all **intercepts** with the axes and **turning points** or **asymptotes**
- ✓ (it is important to be able use and interpret functional notation)
- ✓ Understand the definition of a FUNCTION
- ✓ Understand the INVERSE of a function(swop x and y)
- ✓ Know the inverse of $y = ax + q, y = ax^2, y = a^x$ where $a > 0$
- ✓ Be able to write the inverse in the form y = …
- ✓ Understand the definition of a logarithm: $y = \log_b x \leftrightarrow x = b^y$ where $b > 1$

Figure 6: Just in Time workshops handout (the handouts is from the mathematics subject advisor)

Figure 6 is extracted from the handouts that was used by teachers in the DBE workshop conducted run from the 24th to 26th of May. The handout shows educators hints on the methodology and the mathematics content knowledge on how to teach functions. The handouts contain the information on how to teach mathematics. The extracts from questionnaire and interview data seem to suggest that teachers in the mathematics clusters were engaged in the demonstration, analogy, comparison, reasoning and using models in the lesson. Demonstration on how to prove theorems by using cuttings and measurements of triangles relates to a specialized content of mathematics (Ball, et al. 2008)

4.3.3 Knowledge of Content and Students/ Teaching (KCS/KCT)

In line with Ball, Thames, and Phelps (2008) the data seems to indicate that mathematics teachers in the Siyakhula cluster focused on difficult mathematical problems which learners could not solve and problems where learners made common errors. Participant 10 from questionnaires explains:

> *In the mathematics cluster, the facilitator had suggested formulas to be used when dealing with slow learners. Documents were formulated for both low and highflyers students.*

Participant 3 added:

> *The mathematics cluster helps us with the necessary worksheet that has learners' activities and examples of chapters in mathematics, which is user friendly to a teacher and a learner. We also learnt the strategies of teaching learners who are struggling in mathematics.*

The two participants in the above extracts were not specific on the teaching strategies that they learnt, the evidence from data seems to suggest they focused on problems that students find difficult and they designed simple mathematics documents that could accommodate learners who were struggling in mathematics and as well as high performers.

Participant 2 was specific when responding about what they learn and reported about her learning experience in the workshop organised by EXM3 NGO:

> *The facilitator from EXM3 demonstrated how to introduce probability. Firstly, she explained the probability and asked teachers to come on board to draw inclusive Venn diagram, mutual exclusive, mutual exhaustive events, and complementary events. The facilitator shows how to draw tree diagram using two different sweets. She empowers us with different strategies of teaching probability.*

Participant 7 from the questionnaire commented about what they learned in the DBE workshop:

> *I learnt a lot in these workshops, the facilitator from EXM2 had shown how to find factors using Bingo (mathematical game), I played the game with colleagues. I find it amazingly effective and enjoyed the game I am still using it now with my learners.*

While the above-mentioned participants reported about their learning, participant 5 lamented about the topics that he still needs to learn:

> *I really wish to be developed on teaching content, how to introduce certain chapters and to prove theorem using measuring and pasting, may be my matric results in mathematics would rise. I really need development because chapters like Euclidean Geometry and Probability is new to me.*

This aligns with Participant 10 from the questionnaire who mentioned that:

> *I have not been in any of the NGO's content workshop. There are chapters that are still challenging to me like problems involving minimum and maximum in calculus (application calculus). This chapter is problematic to me. I think I need strategies of how to introduce it.*

Additionally, the attendance of the NGO's content workshop confirms that not all mathematics teachers attended these workshops. These extracts seem to suggest that teachers in cluster workshop learn to use simple formulas when dealing with slow learners. The findings further reveal that teachers learn new strategies of drawing Venn and tree diagrams and learn to find factors using bingo. In these activities amongst other things the facilitator shows the teacher how to introduce the probability. Moreover, participants five and ten stated clearly that they still need development in content. Participant five believed that his results will increase after attending the NGO workshops while participant ten wants to improve the way she teaches calculus (application calculus).

4.3.4 Knowledge of Content and Curriculum (KCC) H

In this study the Knowledge of Content and Curriculum are combined. Ball, Thames and Phelps (2008) defined Horizon Content Knowledge as the knowledge of how topics are linked and knowing which topic in mathematics should be taught in each grade. Zulu (2017) argues that the knowledge of content and curriculum and horizon content knowledge goes together because they

have the same meaning. Similarly, in this study they have the same meaning because participants have mentioned that they decide which textbooks are suitable to teach trigonometry and probability and plan what must be taught and learnt from the curriculum policy. The Horizon Content Knowledge was evident in the NGO and DBE workshop. Participant eight from the questionnaire explains:

> *We also discuss in the NGO workshop the textbooks that can be used to support learners in their learning in each grade. For example, they suggested Mind Action when teaching Trigonometry from 10-12 and Handbook in Probability has good examples.*

Furthermore, Tholah also mentioned the following:

> *We learn that in the cluster workshop algebra, number pattern and functions should be treated together because these chapters have links. Learners should see the integration between chapters that* $y = ax^2 + bx + c$ *is the same as* $Tn = an^2 + bn + c$ *and the graphs are also the same.*

The Just In Time (JIT) workshop documents displays the topics for functions in grades 10 and 11 that need to be taught. It shows that $y = ax^2 + q$ should be taught in Grade 10 whereas, $y = a(x+p)^2 + q$ should be taught in Grade 11. Learners should discover that there is a horizontal and vertical shift.

In this section the findings seem to suggest that in the Siyakhula mathematics cluster teachers have learnt different types of mathematics knowledge. Knowledge was learnt in both DBE and NGO workshops. The DBE workshops focused on moderation, memorandum discussion, methodology and mathematics content knowledge on how to teach certain topics. The NGO workshops seem to focus on the discussion of content, creating models, teaching using technology, training teachers to teach challenging content and choosing the best material to use in class. The next section discusses the characteristics of professional learning communities.

4.4 Characteristics of Professional Learning Communities (PLCs)

The seven characteristics of PLCs has been used to understand a cluster as a professional learning community. I have adopted Stoll, et al. (2006) organisation of these characteristics, which are shared values and vision, collective responsibility, reflective professional inquiry, collaboration, regularity, promotion of group and individual learning and distributed leadership to analyse data.

4.4.1 Shared values and vision

The shared learning vision and values is what motivate the members' participation in a professional learning community. Members of the same community should agree on the same vision and values (Stoll, et al., 2006). The vision should be translated to all members of the community and constitute good quality teaching and learning. The shared vision of Siyakhula mathematics cluster seems to come out when the participants responded to the question about the purpose of the cluster: Phumzile explains:

> *In this cluster we have the common purpose of enlightening the minds of our children since mathematics is a challenging subject. So, we share mathematics techniques in order to improve our teaching. We all have same agenda.*

Participant 1 adds that:

> *Our main purpose is to share information, networking and to develop one another on mathematics content. We also share information with schools close by, to moderate schoolwork and for workshop at times.*

Eleven responses from questionnaires supports the above comments. For example, participant 8 proposed:

> *As mathematics cluster teachers we share ideas and values during the cluster workshops and even outside the workshops because we all have same vision to improve the achievements of learners.*

Participant 4 explains:

> *The purpose of mathematics cluster is to develop educators, to equip educators with different strategies of teaching mathematics and solve educators' challenges in their classrooms. I am interested more in the content discussions because it improves my teachings strategies, I think all of us have the same vision and goals of developing ourselves and learners also.*

In these quotations the participants indicate that members of the Siyakhula cluster (pseudonym) had the vision of improving learners' performance in mathematics, improving their mathematics content of and the teaching strategies. In line with Stoll et al. (2006) the quotes seem to suggest that teachers work with each other to learn better approaches that will enhance their pupils' learning (p. 18).

4.4.2 Collective responsibility

This feature stresses that the members of professional learning community should share the work collectively and take collective responsibility for the learning of students (Stoll, et al., 2006). Further to this, the decision is also shared among the members of PLC where teachers are more active about the decision makers which will increase the participation of the members (Stoll, et al., 2006). The data from both semi-structured interviews and questionnaires have different views about collective responsibility in Siyakhula cluster. Participant 6 in the questionnaire's data further explains:

> *...during the discussions in the workshops lead teachers make sure that we reach consensus in decision making. Lead teachers or the facilitator decides on what must be learnt depending on the need at a given time. Teachers respond positively when they are being tasked by the cluster leaders.*

However, participant 10 mentioned that sometimes members of a cluster do not easily reach consensus when making decisions, but it does not mean they fail to take collective responsibility.

> *As a cluster we usually engaged in memorandum and content discussions. We as mathematics teachers sometimes do not reach the same agreement, especially when discussing the mathematics content.*

The participants from the generated data portray that subject advisors, coordinator, lead teachers and together with the facilitators take collective responsibility in decision making. Participant 7 outlined that:

> *It is the person who is facilitating the workshop decide on the activities that needed to be done. In most cases it is the subject advisor of which they are guided by the annually teaching plan (ATP). Nevertheless, cluster coordinators also have the input.*

Phumzile from the semi-structured interviews supports the above statements:

> *As lead teachers we discuss how we should teach certain topics. We agree on the teaching model and the resources that needed to be used in introducing the lesson.*

The data findings indicate that not all the members of Siyakhula cluster are involved in determining what should be done. Stoll, et al. (2006) stated that PLCs members must be consistent in taking collective responsibility to better the learning of students. However, participants 7 outlined that

decisions are sometimes taken by the leaders of Siyakhula cluster. Other members just follow on what is discussed by the cluster stake holders.

4.4.3 Reflective enquiry

According to Stoll, et al. (2006) reflective enquiry is a conversation that involves examining teachers practice. It involves reflecting on the essential educational issues and problems regarding new knowledge application. Participant 5 explains that:

> *In this cluster we also discuss education issues not related to content for example, when the mathematics paper is written the teacher of mathematics must not appear in the examination room because that will lead to irregularity. The subject advisor also spoke about marks adjustment, when and how does that be considered in the marking centers.*

Tholah felt that:

> *In the beginning of the year (orientation workshop) we get the opportunity to reflect on our practice by analysing the mathematics results for each school in the cluster. In this activity we see the schools that perform better and poorly. Teachers from the performing schools share with other teachers the ideas, skills, resources, and knowledge used that lead the learners to perform well.*

In contrast, the data from the questionnaires did not show that the teachers reflect on their practice.

4.4.4 Collaboration

Collaboration between teachers is an important characteristic that determines the success of any professional learning community because it encourages working together to promote learning and sharing of tasks where teachers help one another in doing common activities (Stoll et al. 2006). In the semi-structured interview participants highlighted that the cluster coordinator ensures that teachers work collaboratively to support each other. Phumzile mentioned:

> *We do a lot of sharing, interchange, all that stuff. In the mathematics cluster, the newly appointed teachers are supported by everything in terms of resources, curriculum coverage, revision tips, teaching challenging topics.*

Mathematics teachers seem to support one another in many ways such as team teaching, sharing teaching methods, and mathematics materials. Participant 8 said:

We share ideas, worksheet, teaching skills, previous question papers, memorandums and methods of teaching mathematics because we are a group of educators from different schools with different experiences and from different department.

Tholah mentioned how they learn in the NGO workshops:

At EXM3 workshop we solve mathematical problems as a group, we did group presentations, make mathematics model and we learn how to play mathematics games on a computer. In these workshops we work as a family to improve teachers and learners' performances.

Additionally, Participant 10 supports the above statement:

In EXM1 workshop, we learn collaboratively to solve challenging mathematical problems using different approach like teaching model. We were encouraged to make our own model to demonstrate pyramid, rectangular prism, cylinder, cone, cube.

The data also reveals that collaboration in PLCs is also takes place outside of the workshops where teachers share resources and do team teaching. Participant 9 said:

In a mathematics cluster we work together as a group. When we are setting cluster activities, we assist one another in terms of choosing the textbook that has got good examples and we also invite well experienced teachers and lead teachers to come and teach in our schools. We learn new methods and strategies.

Participant 8 highlighted sharing through WhatsApp:

We are also collaborative informally outside the workshop by using WhatsApp group. When someone posted the problem, we do it and send it back. On WhatsApp, teachers send documents, tests, memorandum, worksheets, assignments, projects and so on.

Additionally, participant 7 from the questionnaires mentioned:

We share our experiences with other teachers. We also share skills, knowledge, and other useful information like exchanging ideas on to motivate learners.

The findings seem to suggest that in the Siyakhula (pseudonym) mathematics cluster there is collaboration that takes place during the workshop and outside of the workshops. It is display from the findings that teachers help one another, share resources, exchange ideas, skills, and knowledge. The findings show that mathematics teachers get an opportunity to work together in groups

discussing and solving mathematical problems. These findings align with the findings of another study conducted by Jita and Ige (2019) who asserted that teachers changed from a personalized or individual lesson plan to a clustered lesson plan after attending the workshops. The findings seem to reveal that teachers are supported by useful resources, ideas, and methods of teaching.

Participants also mentioned that teachers of the cluster work collaboratively outside of the workshop using WhatsApp group.

4.4.5 Regularity

Stoll, et al. (2006) added that workshops meeting for teacher learning communities shouldregularly involve structured and unstructured experiences. The data findings show that teachers also meet informally outside of workshops by using a WhatsApp group. This finding reveals thatthey meet once a term in DBE workshops.

Phumzile confirms by saying that:

> *We meet quarterly or once per term unless there is an emergency of setting papers or discussing memorandums all that. The cluster meeting set by the DBE and is formal.*

This is supported by Khenani who explains that:

> *Every term we meet to moderate for content workshops and other mathematics related issues like if they are queries, setting of papers, cluster papers where need be, School Based Assessment (SBA) training.*

However, one participant (Neleh) said:

> *We had learning before for example like 1+9 workshop where we will be able to meet on each and every Monday of every week to discuss certain topics that are going to be taught in that week and how to introduce them, how to assess them and how to give homework's, so we planned the work for the whole week. It was organised by the Department of Basic Education and facilitated by the subject advisors and cluster coordinator.*

The findings indicated that there is also an informal meeting where teachers meet outside of the workshop using WhatsApp group Below is the evidence provided by participant 2:

> *We have a WhatsApp group where we communicate with each other. We communicate almost every day with colleagues. We also get lead teachers who assist us in our schools.*

Similarly, participant 4 stated that:

> *We support each other through WhatsApp groups. In this group, we get an opportunity to ask anything related to mathematics issues. We do not have stipulated time stating when teachers should ask questions in the group.*

The findings depict that the NGOs do not meet regularly:

> *I attended EMX3 workshop for three months, EXM2 workshop (attended three times a year) and EMX1 six times a term.*

To summarise, the findings do not show that teachers meet on regular basis. In contrast, the findings seem to suggest that some of the workshops organised by the DBE like the one mentioned by Neleh and conversation in WhatsApp group are more regularly used to communicate.

4.4.6 Group as well as individual learning

This feature refers to the nature of learning in PLCs. Stoll, et al. (2006) argues that all teachers and their colleagues in PLCs are learners where they learn collectively and individually. Teachers learn in a group where they share and critically interrogate their practice in an ongoing and growth promoting way. The data shows that teachers work as a group and individual when doing the activities of the Siyakhula (pseudonym) cluster. It appears from data that the mathematics cluster encourages the collaborative learning, but participants mentioned that there were times where teachers work alone in some activities. Khenani explains in this manner:

> *Teachers work as a group most of the time, but they are those cases where each teacher will need to work individually in order to benefit from that individual challenge it depends on the case.*

The above statement was supported by participant 7 who stated that:

> *All learning activities were highly effective. Normally the weekend away workshop start with pre- test and end with post- test. Teachers worked as an individually when writing pre and post-tests and then discussions and presentation as group follows. These test usually be set on the topics that are problematic to us for example, Euclidean Geometry, Probability, Application Calculus and Financial Mathematics. The most useful is the content workshop where we are helping each other with different strategies of teaching.*

Regarding this feature of PLCs Khenani and participant 7 seem to agree that teachers learn individually when writing pre and posts test workshop activities, especially on challenging topics. The discussions and presentations were in groups while pre and post-tests is for an individual teacher. These findings confirm that Siyakhula mathematics teachers learn by participation where teachers from different schools work collaboratively with other teachers. It came out from findings that they also do networking with neighbouring schools.

4.4.6 Leadership

Stoll, et al. (2006) state that in PLCs leadership is shared among members of PLC. Furthermore, in PLCs the leadership amongst all members is encouraged. The data from interviews and questionnaires indicated that the leadership is shared. Khenani, the subject advisor clarified:

> *In this cluster leadership is promoted because, all mathematics teachers have equal chance of leading, discussing and presentation. The learning is collective whereby cluster members share information and working collaboratively to solve problems, do planning and also improve learning opportunities.*

Participant 8 from the questionnaire describes that:

> *We also have leaders for this clusters for example NGO's and DBE facilitators, lead teachers, secretary, cluster coordinator and subject advisor. These leaders help the mathematics teachers to improve the performance of their students because we get an opportunity to ask lead teachers about difficult questions and strategies used in solving mathematical problems. It is the lead teachers that coordinates team teaching in the cluster.*

Likewise, Tholah elaborated:

> *The leadership is demonstrated by the leaders of this cluster by assisting teachers with tasks distribution, leading the discussion, asking help from the NGO's, organising team teaching and winter classes. Our cluster leaders they work very hard in supporting other teachers like subject advisor is responsible to seek help from NGO's and facilitate memorandum discussion, assist teachers with SBA activities.*

To add on what was said by Tholah, participant 7 from questionnaire stated that:

> *The NGO's facilitators organises the teaching resources where they prepare worksheet for teachers and the learners, they always come with simple methods and understandable. Encourages us to use technology in our lesson.*

The findings clearly suggest that the duties are shared equally for example lead teachers help other teachers with content knowledge and the different methods to attempt certain problems. The subject advisor, coordinator, lead teachers and all members have an equal chance to lead the discussions. This indicates that leadership is distributed among the members of this cluster. In addition, the participants have outlined that NGO facilitators prepares the worksheets, teaching material and develop teachers in mathematics content.

4.5 Conclusion

I presented detailed analysis of data using Birman, et al.'s (1999) features of professional development; followed by Ball et al.'s (2008) mathematics teacher knowledge and lastly, Stoll, et al. (2006) characteristics of a professional learning community. In the following chapter I present the discussions of the findings, recommendations for future research and the conclusion.

CHAPTER FIVE
DISCUSSION, RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

In the previous chapter I have used the conceptual frameworks; of Birman, et al. (1999); Ball, et al. (2008) and Stoll, et al. (2006) to present and interpret the data deductively. This chapter discusses the findings of the study in relation to three research questions. The chapter also presents the implications of the findings, limitations, and the recommendations for future research.

5.2 Discussion of findings on each research questions

This section discusses the findings according to each research question in relation to the literature. The research questions that underpinned the study were:

1. How do teachers learn in a mathematics cluster?

2. What type of mathematics knowledge do teachers learn in a mathematics cluster?

3. To what extent does the mathematics cluster adhere to the features of a professional learning community?

5.2.1 How do teachers learn in a mathematics cluster?

This research question was based on teacher learning in a mathematics cluster. While Mphahlele (2014) asserted that clusters are used only for moderation of learners' work, the findings of this study seem to suggest that mathematics teachers engaged indifferent learning activities. These learning activities include learning from facilitators demonstrating how to teach mathematics topics using different strategies. For example, they learn ɒdraw circles on Euclidean Geometry using a computer. The activities also include group discussions and individual activities. The individual activities take place when they write pre- and post-tests. Pre-tests was written before the workshop started and post-tests was given to teachers after the content discussion. There is evidence from the findings which suggests that learning occurs outside of the workshop and this learning takes place in a WhatsApp group for the mathematics teachers. Mathematics teachers learn to identify unfair questions and sections that learners lose a lot of marks during November examination.

The data indicated that mathematics teachers who engage in NGO workshops learn how to teach using mathematical model such as cuboid, cylinder and rectangular prisms. The technology is used in the mathematics lessons and all participants from semi-structured interviews concurred that teachers learned to teach using a computer and projector when dealing with probability, Euclidean geometry as well as other chapters. Hammond (2017) asserted that in PLCs, teachers discussed different teaching strategies, learn from each other by sharing and becoming better teachers. The findings revealed that teachers of the Siyakhula cluster learn to find factors by playing mathematics games called Bingo. In addition, teachers learn to search on google mathematics lesson plans, study material and previous question papers.

The findings of this study indicates that mathematics teachers learn outside of the workshop by using the online platforms such as WhatsApp. It appears in the data findings that the WhatsApp group plays an important role in the learning of teachers because they discuss important concepts and share teaching documents like tests, memorandums, worksheets, circulars, and they post challenging problems in the group. This relates to the study of Blitz (2013) who established that the online learning allows teachers to share knowledge and experiences are well-timed and presented in a comprehensive manner. She further explained that teachers who work collaboratively online develop a sense of community and their pedagogical knowledge and knowledge of the subject improved. The findings showed that the WhatsApp group plays an important role in the learning of teachers because they discuss important concepts and share teaching documents and they also post challenging problems in the group. Similarly, Stepanek and Barton (2012) who view online learning as the platform for teachers to discuss problems of practice, share performances of their students and develop teaching instructional strategies and share resources. Additionally, they stated that teachers can also conduct meetings using platforms like WhatsApp, and WebEx to discuss their teaching (Stepanek & Barton, 2012). Based on the evidence provided, the findings of this study seem to agree with Jita and Mokhele (2014) that through clusters teachers can learn collaboratively and share their skills and experiences.

The findings revealed that six out of eleven participants acknowledged that teachers learn by observing other teachers from other schools teaching methods. Participants further stated that teachers learn together as a team, from group presentations and shared teaching strategies.

5.2.2 What type of mathematics knowledge do teachers learn in a mathematics cluster?

The second research question of this study aims to understand the mathematics knowledge that teachers learn in Siyakhula mathematics cluster. Teachers acknowledged that in NGOs and DBE workshops, they acquired different types of mathematics knowledge and skills. Teachers discussed how the mathematics content could be delivered to learners to make sure that learners better understand. In the NGO's workshops teachers were given the activities to perform, some of these activities were based on the mathematics content from previous years question papers. These activities done in workshops seemed to include different types of mathematics knowledge such as the Common Content Knowledge, Specialised Content Knowledge, Knowledge of Content/Student/Teaching and Knowledge of Content and Curriculum (Horizon). The findings also suggest that mathematics teachers learn to use mathematics resources for example laptops, projectors, scissor, paper, pencil, whiteboard and white board makers. Teachers learn to choose the correct formulae and they learn new ways of introducing topics. It is clear from the findings that during the mathematics workshops teachers were given activities that accumulate different types of knowledge. The research findings showed that these activities helped teachers to work collaboratively.

In line with the literature on mathematics knowledge (Zulu & Bertram, 2019; Ball, et al., 2008) the findings also suggest that mathematics teachers learn Common Content Knowledge (CCK) across all types of mathematics knowledge where a teacher can identify when students have given the wrong answers, recognising incorrect answers and to use the mathematical notation correctly This is in line with the study of Carrillo, Climent, Contreas and Munoz-Catalan (2013) who asserted that teachers should have the skills of resolving students' problems and correcting errors made by the students.

The findings revealed that teachers learnt to solve mathematical problems such as finding the factors for quadratic equations. The participants clearly confirmed that teachers learn the content such as Euclidean Geometry, Probability, Application Calculus problems and Financial Mathematics. The common findings of this study suggests that mathematics teachers learn the Specialised Content Knowledge (SCK) where they learn to solve challenging problems involving maximum and minimum in application calculus. The data further stated that in the NGO's workshop teachers learnt the skill of proving theorems by measuring angles. The findings seem to

suggest that new teaching strategies were learnt, such as demonstration of how to draw a venn diagram.

In the NGO's workshops teachers were trained to teach all the chapters with confidence because they prepare worksheets to be discusses in the workshop and the worksheets are given to learners afterwards. The findings revealed that teachers have the skills of teaching the challenging topics. This corresponds with Mewborn (2001) who described that teachers should have the knowledge of content and teaching because activities require mathematical knowledge to solve the problems of mathematics. He further mentioned that teachers choose examples that are suitable to be used in the introduction of the subject. Therefore, the Knowledge of Content and Teaching (KCT) seem to be learnt in the cluster.

The findings indicated that the Knowledge of Content and Curriculum (KCC) was learnt in the DBE workshops, this was evident by the respondents when they highlighted that teachers in the mathematics cluster, learn how the curriculum across different grades are linked (grade 10-12) and which resources are used in each grade. The findings pointed out that teachers learn to select relevant teaching resources, relevant mathematics textbooks and the pacing of mathematics topics. These findings are in line with Carrillo, Climent, Contreas and Munoz-Catalan (2013) who explained that "teachers should have the knowledge of choosing certain material for learning or choosing a textbook, includes knowledge for curricula, knowledge consequential by external bodies" (p.285). Lastly, the findings seem to suggest that the interaction with other teachers, external agents NGOs and subject advisor enhanced teachers' knowledge and development. It was acknowledged that there were challenges in terms of time allocation for activities and that some teachers did not attended the NGOs workshops.

5.2.3 To what extent does the mathematics cluster adhere to the features of a professional learning community?

The third research question aimed to understand the extent to which the mathematics cluster adheres to the features of professional learning communities. The Siyakhula Cluster reflects the following characteristics of a PLC: shared values and vision, collaboration, promotion of group and individual learning and distributed leadership. However, collective responsibility, reflective professional inquiry, and regularity of meetings were unclear from the findings. It emerged from

the data that mathematics teachers engaged in planned and incidental learning. It was evident that teachers engaged in various mode of learning.

The findings showed that the Siyakhula cluster teachers have the common purpose of enlightening the minds of the children. Participants have mentioned that teachers assist in neighboring schools to improve learners' achievement. It is evident from the findings that teachers shared the same values and the vision to improved student performance. This shared vision seems to be in line with the mandates of the Department of Basic Education to improve poor performance in mathematics. This mathematics cluster seems to be based on improving performance in mathematics. Poor performance of learners in mathematics has been highlighted as a global challenge. Hence, Venkat and Spaull (2015), stress that the poor performance in South African learners requires short learning intervention programmes for teachers. Therefore, activities of Siyakhula cluster could be perceived as intervention programmes to improve learners' performance in mathematics.

The findings indicated that collaboration among teachers in the Siyakhula mathematics cluster occurs in the workshops and in WhatsApp groups. The findings of this study shows that mathematics teachers shared resources such as worksheets, teaching skills, ideas,previous question papers and memorandums. Furthermore, teachers collaborate by observing otherteachers teaching in order to improve their own practices. The element of sharing the resources appeared to be mostly done inside and outside of the workshop using WhatsApp groups and this reflected a good relationship among the cluster members. This was in line with the study of Khenan(2019) who highlighted that PLC is a platform for teachers to share, observe, and discuss one another's practices and strategies used in the classrooms. This is supported in Cereseto's (2015) study that teachers in PLC work cooperatively when they share their learning with one another. Kenan (2019) adds that collaboration is facilitated among teachers on the development of impactful learning material to improve student instruction. The participants specified that in this mathematics cluster, sharing is used as the best weapon to acquire skills, knowledge and to disseminate the information. These findings seem to be in line with Mitchell and Jonker (2013) who established that teachers benefited greatly from being a member of a cluster, which includesnetworking with other teachers, learning new skills, information and solving problems jointly. Thefindings also revealed that teachers collaborated when they check each other's continuous assessment tasks and learners' portfolios. This kind of collaboration in the Siyakhula mathematics

cluster seems to be associated with contrived collegiality because moderation is an administrative activity which is regulated by the DBE. Forte and Flores (2014) clarifies that contrived collegiality is associated with formal and specific activities at department or subject matter level and in many cases, these are driven by top-down initiatives from the Ministry of Education and Management" (p.98). This means that teachers work together to implement the mandated tasks. The findings did not indicate clearly about collaboration that was initiated by teachers themselves as envisage in the features of PLCs. The study conducted by Zulu and Bertram (2019, pp.114-115) suggested that "contrived collegiality could be used in transforming a cluster from administratively-regulated teacher collaboration to a teacher-driven collaborative learning space."

Leadership in mathematics clusters appeared to be shared among subject advisors, cluster coordinators, lead teachers, teachers, NGO and DBE facilitators. Lead teachers were tasked by the subject advisors to facilitate content workshops. It was displayed from the finding that teachers share leadership roles and distribute duties equally amongst all the members of the cluster. Chow (2015) stated that leadership should be shared with the external and internal authorities. Furthermore, Brodie (2019) suggested that leadership in a PLC should be supported by providing time, space and resources where required. The findings of the recent study by Thornton and Cherrington (2019) argue that the members of PLCs should make time for professional conversation, coaching and mentoring to support the teaching practices.

Participants confirmed that teachers work individually when writing pre and post-tests. They further mentioned that collective learning occurred when teachers work in groups, discussing the papers they have written. Brodie (2013) asserts that learning in a PLC could result in individual and collective learning. This view suggests that teachers in a PLC learn together in order to achieve the same objectives. Ceresto (2015) mentioned that teachers learn as individuals and then they share their learning with other colleagues while learning collaboratively.

The findings of this study suggest that teachers acquired different skills when working together with other teachers. Stoll, et al. (2006) stated that reflective inquiry is an important feature of a PLC. The data indicated that mathematics teachers have conversations about their profession. The participants reported that teachers have dialogues about educational matters to improve teaching and learning. It came out from the findings that the reflective inquiry occurs in the DBE cluster workshops where the subject advisor asked teachers to reflect on their teaching practice and the

marking of mathematics final papers. However, reflective inquiry was not mentioned by many participants and the data did not clearly show that teachers had undertaken reflections about their own teaching practices. Khenan (2019) explains that constructive dialogue is shown in a good PLC based on the shared norms, beliefs and values that allow the analyses of individual and collective performance. One could not just say that reflecting on teaching practices is one of the shared norms because it the subject advisor who asks teachers to reflect on their teaching practice.

The findings of this study did not clearly indicate that teachers of the Siyakhula mathematics cluster decide on what must be learnt in a PLC. The findings suggest that only the subject advisor and NGO facilitator determine what should be learnt. This situation seems to contrast with the function of PLCs because all the members of the PLC should collectively determine what should be learnt. Collective responsibility requires that all members in a PLC come together to build a collective understanding of how all their learners learn, and to improve it (DBE & DHET 2011, p.14).

It was not clear if the meetings via WhatsApp groups occurred regularly. However, the WhatsApp groups seem to provide a platform for these teachers to meet. The formal workshops and informal meetings of teachers outside of the workshops appeared to be irregular. Beach (2012) argues that teachers in PLCs can also support their colleagues using online methods where they learn together, mentor each other, give feedback, and access learning material that supports their learning. Beach (2012) further highlighted that using online platforms makes it easier for teachers to work remotely to support one another through shared planning, development of curriculum, resources, and teachers.

5.3 Implications of the Findings

The findings suggest that teacher learning that is taking place in the Siyakhula cluster. The participants reported that demonstrations used by the facilitator help them to improve the quality of their teaching and learning of mathematics in their respective schools. The findings reveal that DBE cooperated with the NGOs to initiate professional development activities for the Siyakhula cluster. For the clusters to function as PLCs, all the stakeholders including teachers, the DBE and NGOs should work together to promote meaningful learning in the teacher clusters.

The findings have shown that not all teachers have attended NGO workshops, therefore the subject advisor should ensure that all teachers are given equal opportunities to learn to teach using

technology in the learning and teaching of mathematics. The DBE (the subject advisors) should also separate dates for moderation and content discussion so that teachers will get enough time to engage in the discussion of Specialised Content Knowledge, Knowledge of Content and Students, Knowledge of Content and Teaching and Knowledge of Content and Curriculum (Horizon).

The findings of this study are draw attention to the importance of the online professional learning communities because the findings indicate that the WhatsApp groups enable teachers to meet online. In this study teachers were able to learn informally from one another through WhatsApp groups. The findings have shown that reflection in Siyakhula cluster was not aligned with PLC reflection practices where teachers share their teaching challenges, and learners' misconceptions. The activity on reflection was about determining the poor performance of the schools. The findings also indicated that decisions about what to be learnt in the Siyakhula cluster is determined by facilitators however, it should have included the teachers as well. There is still a need for the DBE to review and simplify the roles of the PLC.

The findings indicated that the NGO facilitators and subject advisor promoted collaboration during cluster workshops. The lead teachers of the mathematics cluster could also adopt collaborative learning among teachers in their schools. The findings have shown that NGO facilitators seem to be more creative when delivering the mathematics content. This could be due to their experience and expertise in teaching mathematics. The shortage of resources is an outcry in schools; however, the NGO facilitators were teaching in well-resourced schools with advanced technology that allows them to teach mathematics with a laptop and a projector. The NGO facilitators then assisted mathematics teachers with the advanced skills of teaching mathematics using laptops. Therefore, it is important for the Department of Basic Education to support the clusters with resources for technology. The PLCs requires resources in order to function effectively.

5.4 Limitations of the Study

The participants were afraid of being part of the interviews because of the Covid-19 pandemic. My position as a mathematics teacher, teaching grades 10-12 in the same cluster could have impacted the participants to freely respond to the questions of this study. As a researcher studying my cluster, I found myself being biased on certain issues. Additionally, using the document analysis could limit my data because documents were not easily accessible during lock down. Furthermore, I could not observe the mathematics cluster and see how teachers participated and engaged in the activities of the cluster and I had to rely on what was said in the interviews and

questionnaires. The questionnaire was prepared within a short period; this might influence the results. Lastly, the findings of this study may not reflect how other mathematics teachers in other clusters learn because the scale of the study was small.

5.5 Recommendations for Future Research

Recommendations for future research about teacher learning in professional learning communities, is that the researchers should focus on a larger scale of data and compare mathematics clusters from different districts. I recommend that further research could observe teachers' lessons before and after they have joined the cluster in order for the researcher to see how teachers implement what they gained from meetings and workshops to improve teaching practice.

5.6 Conclusion

This research study investigated how teacher learning occurred in a mathematics cluster (Siyakhula). The study findings revealed that teachers learn by interacting with the facilitators, other teachers and doing the tasks which were demonstrated by the facilitators. There was also learning that was taking place outside of the workshop, this learning takes place on WhatsApp groups. The findings have shown that specialised content knowledge, knowledge of content and students, knowledge of content and teaching and knowledge of content and curriculum (horizon) were learnt. Finally, this study found that the Siyakhula cluster adheres to some of the features of PLCs. These features include a common vision and values, distributed leadership among teachers and facilitators, collaboration, individual and group learning. However, regularity of meetings, reflective inquiry and collective responsibility were unclear from the data.

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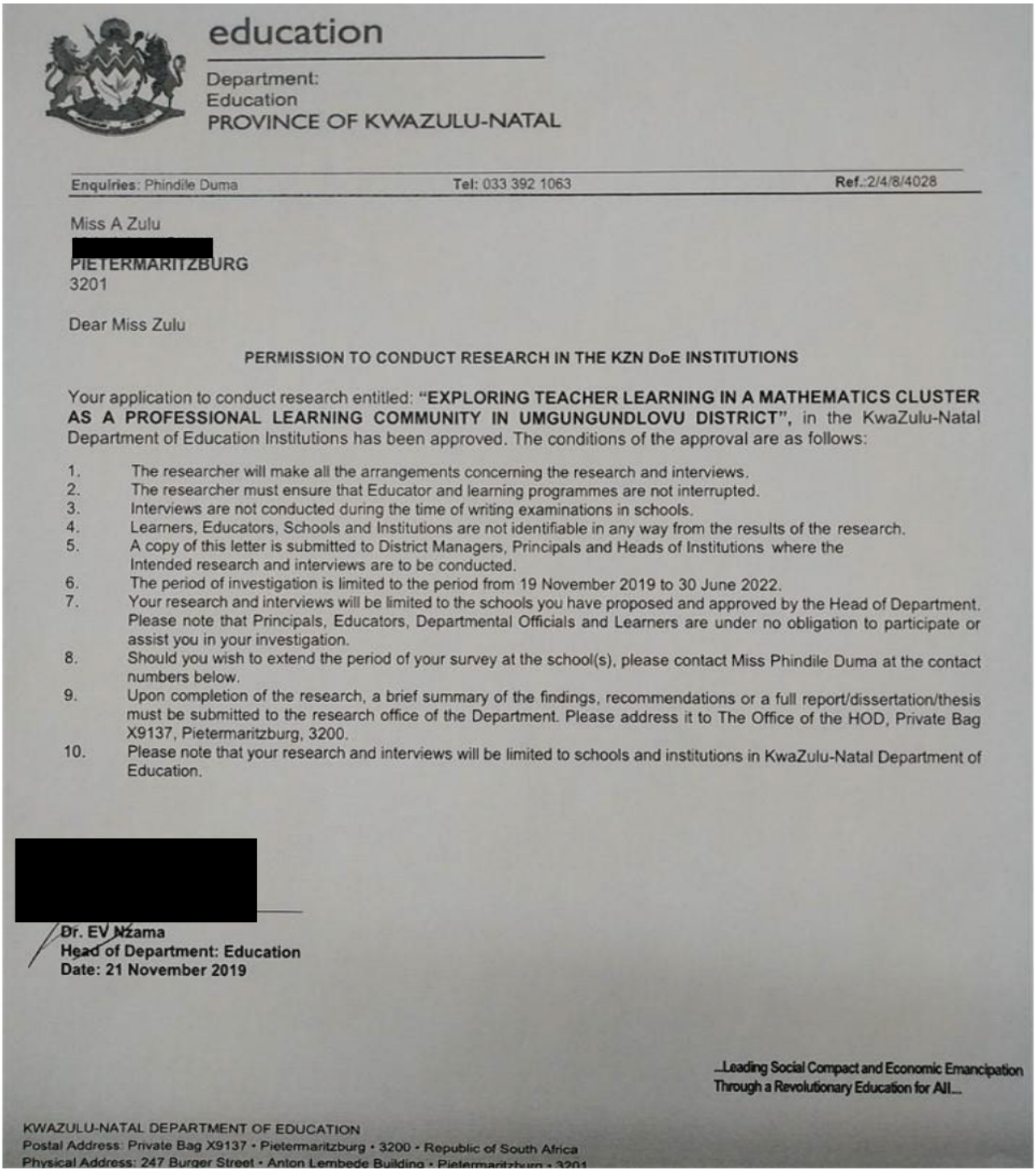
Appendix A: Permission to conduct research in the KZN DoE institutions



education

Department:
Education
PROVINCE OF KWAZULU-NATAL

Enquiries: Phindile Duma Tel: 033 392 1063 Ref.:2/4/8/4028

Miss A Zulu
[redacted]
PIETERMARITZBURG
3201

Dear Miss Zulu

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"EXPLORING TEACHER LEARNING IN A MATHEMATICS CLUSTER AS A PROFESSIONAL LEARNING COMMUNITY IN UMGUNGUNDLOVU DISTRICT"**, in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 19 November 2019 to 30 June 2022.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers below.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

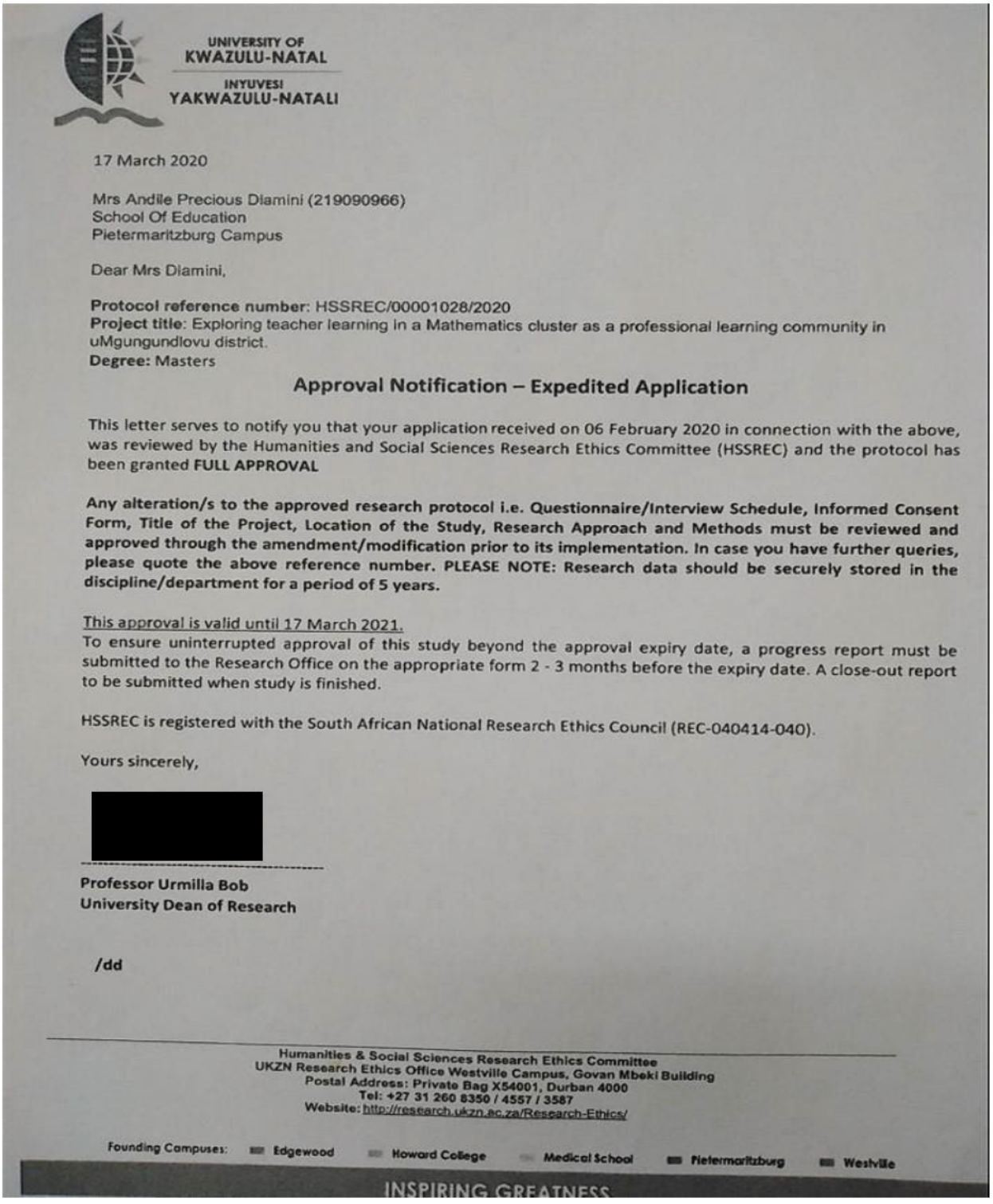
[redacted]

Dr. EV Nzama
Head of Department: Education
Date: 21 November 2019

...Leading Social Compact and Economic Emancipation
Through a Revolutionary Education for All...

KWAZULU-NATAL DEPARTMENT OF EDUCATION
Postal Address: Private Bag X9137 • Pietermaritzburg • 3200 • Republic of South Africa
Physical Address: 247 Burger Street • Anton Lembede Building • Pietermaritzburg • 3201

Appendix B: Ethical Clearance Letter



UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

17 March 2020

Mrs Andile Precious Diamini (219090966)
School Of Education
Pietermaritzburg Campus

Dear Mrs Diamini,

Protocol reference number: HSSREC/00001028/2020
Project title: Exploring teacher learning in a Mathematics cluster as a professional learning community in uMgungundlovu district.
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 06 February 2020 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**

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

This approval is valid until 17 March 2021.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

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

Yours sincerely,

[redacted]

Professor Urmilla Bob
University Dean of Research

/dd

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

Appendix C: Informed Consent for Participants

[redacted]

Pietermaritzburg

3201

27 November 2019

Dear Sir/Madam

REQUEST FOR PARTICIPATION IN RESEARCH PROJECT

My name is Zulu A.P (Student No. 219090966) a Master of Education student in the School of Education at the University of KwaZulu-Natal (Pietermaritzburg Campus). As part of the requirement for this degree, I should conduct a research project. The title of my research study is: Exploring teacher learning in a Mathematics cluster as a professional learning community in uMgungundlovu district. The aim and purpose of this research study is to explore and understand teacher learning in a Mathematics cluster as a professional learning community (PLC). It also examines the kinds of Mathematics knowledge learnt and the extent to which the Mathematics cluster function as PLCs. The research is supervised by Dr. Free Queen Bongiwe Zulu a lecturer at the School of Education in the University of KwaZulu-Natal.

You have been identified to participate in the interview session as member of the Mathematics cluster. I than humbly request to conduct interview with you. The interview should last approximately 45- 60 minutes. I will record your views in writing and tape record the interview. Follow-up interviews may be conducted if necessary. The data will be kept anonymous, it will be not possible for it to be linked to your name and the cluster. You will not be disadvantaged if you choose not to participate or if you leave or withdrew from the study.

In the event of any problems or concerns/questions you may contact me, my supervisor or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

My contact number

Email: [redacted] Cell: [redacted]

Supervisor

My supervisor is Dr. Free Queen Bongiwe Zulu who is located at the School of Education, Pietermaritzburg campus of University of KwaZulu-Natal.

Email address: ZuluF1@ukzn.ac.za . Tell: 033 260 5723

UKZN Research Office

Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557- Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

Participation in this research study is voluntary and teachers may withdraw participation at any point. In the event of refusal/withdrawal of participation teachers will not be penalized. There are no consequences for teachers if they withdraw from the study.

No costs will be incurred by teachers as a result of participation in the study and there are no incentives or reimbursements for participation in the study.

All names of schools and participants will be changed and pseudonyms will be used so that schools and participants remain anonymous. Information provided by teachers will remain confidential and will not be shared with anyone else. Data generated through lesson unstructured observations, semi-structured interviews and document analysis will be stored in my supervisor's office, at the School of Education, Pietermaritzburg campus for five years, and thereafter be destroyed.

Thank you for your cooperation.

Yours in Education

Andile Zulu

DECLARATION OF CONSENT

I, _____ have been informed about the study entitled: Exploring teacher learning in a Mathematics cluster as a professional learning community in uMgungundlovu district by Andile Zulu.

I understand the purpose and procedures of the study.

I have been given an opportunity to ask questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at [redacted].

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557 - Fax: 27 31 2604609

Email:HSSREC@ukzn.ac.za

Additional consent, where applicable

I hereby provide consent to: (Please circle response)

Observe lessons and classroom activities	YES / NO
Audio-record my interview / focus group discussion	YES / NO
Complete questionnaires	YES / NO

_____ _____

Signature of Participant **Date**

Appendix D: Interviews Schedule

Title: Exploring teacher learning in a Mathematics cluster as a professional learning community in a district.

Thank you so much for being available for an interview and thank you for signing the consent form, so you are aware that this project is part of my studies at UKZN. Everything that you say will kept confidential. This interview should take about 45-60 minutes.

1. What is your age range?
2. What are your qualifications?
3. How long have you been teaching?
4. What grades do you teach mathematics this year?
5. What is your portfolio in mathematics cluster? (if there any portfolios)
6. How often do you meet as a mathematics cluster or mathematics teachers?
7. How many workshops have you attended last year?
8. Who invites members of the mathematics cluster for the workshop or meetings?
9. What do you understand by the term teacher learning?
10. Is there a learning that is taking place in this mathematics cluster? If yes, how does this learning happen? Who facilitate this learning?
11. Are there any activities that teachers do during the workshops? Please describe these activities if there are any. What do you learn from these activities?
12. Who pre-determine what should be learnt in your cluster?
13. How useful and not useful is the learning that takes place in your mathematics cluster to your teaching practice? (Why?)
14. Describe any learning experience that you have experience in the mathematics cluster. Who initiated it? Who facilitated it? What were activities? What was the focus? What were the resources used and who provided them?
15. Do you meet as mathematics teachers outside of the workshops? (How often do you meet?)
16. How do you support one another outside of the workshops?
17. How do you feel about yourself regarding learning in the mathematics cluster? Does it improve the sense of being a professional?
18. What does it mean for you to say that your mathematics cluster is a professional learning community?

    Thank you.

Appendix E: Questionnaires for Mathematics Cluster Teachers

Consent for participants

My name is Andile Dlamini I am a student doing Masters of Education from the University of KwaZulu-Natal. Due to the Covid-19 pandemic we are facing I was unable to observe the in workshops of the cluster. I humbly request you to tell me about activities of the cluster by responding to the questionnaire. The purpose of this research is to explore teacher learning in a mathematics cluster as a professional learning community. It also examines the kinds of mathematics teacher knowledge learn in a cluster and the extent to which this mathematics cluster operates as professional learning community. This study has been ethically reviewed and approved by the Department of Basic Education and UKZN Humanities and Social Sciences Research Ethics Committee (HSSREC/00001028/2020). Your participation in this study is voluntary and I will not share your responses with anyone.

The research is supervised by Dr. Bongie Zulu a lecturer at the School of Education in the University of KwaZulu-Natal. If you have any questions about this study, please contact me: Andile Dlamini on [redacted] or email me at [redacted]

QUESTIONAIRES FOR PARTICIPANTS

Title: Exploring teacher learning in a Mathematics Cluster as a professional learning community in uMgungundlovu district.

A. Biographical Information

1. What is your gender?	**Options**	**Tick Here**
	Female	
	Male	
2. What is your age range?	**Options**	**Tick Here**
	20-29 years	
	30-39 years	
	40-49 years	
	Above 50	

3. How long have you been teaching?	**Options**	**Tick Here**
	0-5 6-10 11-20	
	21-30	
	Above 31	
4. What are your teaching qualifications	**Options**	**Tick Here**
	Professional Diploma eg SSTD	
	B.A or BSC + PGCE	
	BEd	
	Bed Hons	
	Other (please specify)	
5. What is your portfolio in mathematics cluster?	**Options**	**Tick Here**
	Subject advisor	
	Lead teacher	
	Cluster coordinator	
	Just a member	
	Other (please specify)	
6. How long have been involved with this cluster?	**Options**	**Tick Here**
	1-5 years	
	6-10 years	
	11-20 years	
	More than 21 years	
7. What grade do you teach this year?	**Options**	**Tick Here**
	Grade 8	
	Grade 9	
	Grade 10	
	Grade 11	
	Grade 12	

8. Please describe the purpose of the formation of the mathematics cluster

9. How many workshop have you attended since you joined the mathematics cluster?

Answer_____

In the table below, please provide details of those workshops

Date	Facilitator of the workshop	What was the purpose of the workshop	What did you learn?

9. How often do you have these workshops for the cluster?

10. Who normally decides what must be learnt in the workshop?

11. Please tell me more about the activities that you engage in during the cluster meetings/ workshops?

12. Which of these activities do you find most useful? Why?

13. How do you support one another outside of the cluster?

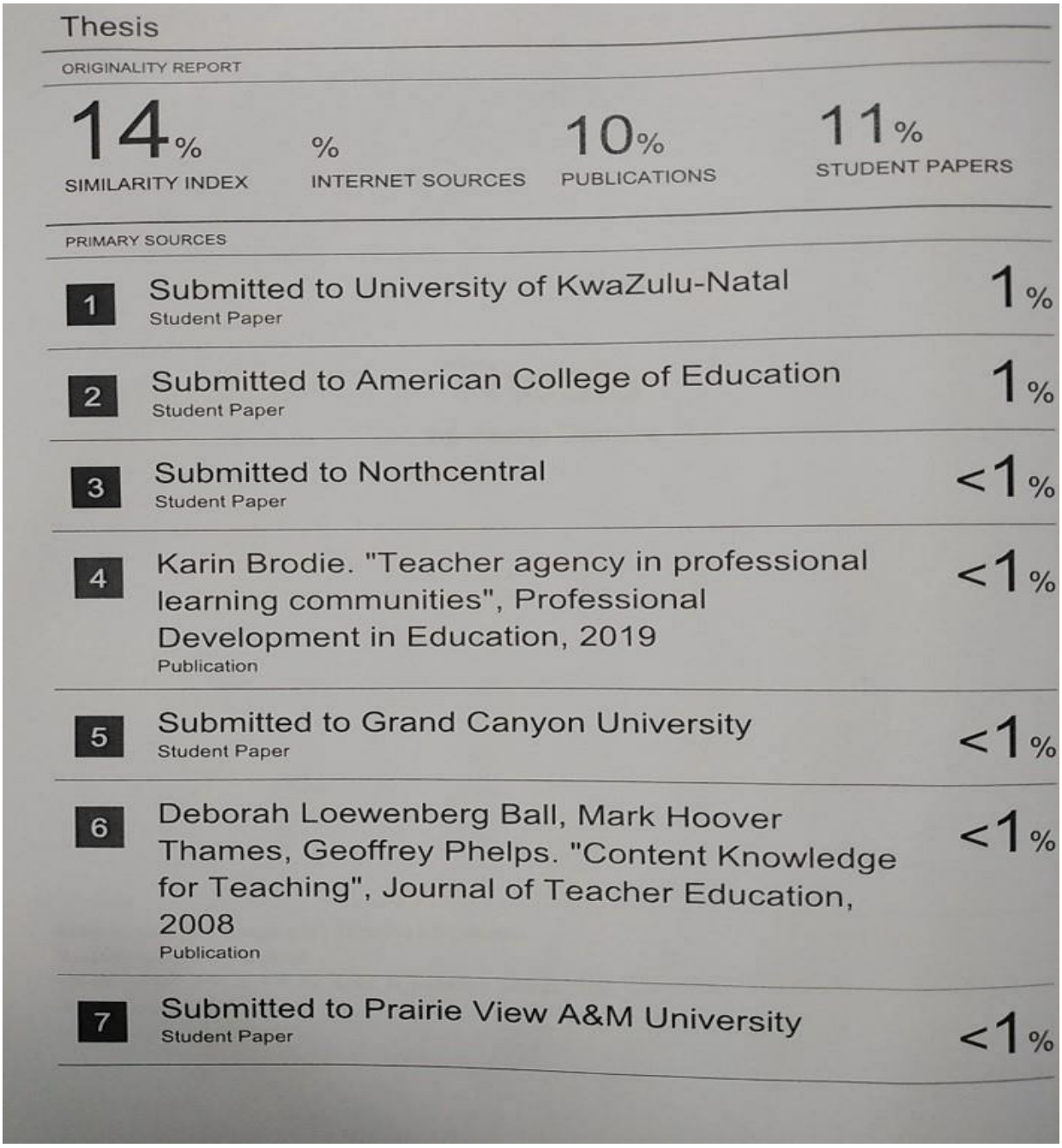
14. How does the mathematics cluster help in teaching and learning of mathematics?

15. How does learning in cluster promote the sense of being a professional?

16. Please describe the most valuable learning opportunity that mathematics cluster offers you as a mathematics teacher? When did it occur? Who initiated it? Who was facilitating it? What did you learn?

Thank you

Appendix F: Turnitin Report



Thesis

ORIGINALITY REPORT

14%	%	10%	11%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of KwaZulu-Natal Student Paper	1%
2	Submitted to American College of Education Student Paper	1%
3	Submitted to Northcentral Student Paper	<1%
4	Karin Brodie. "Teacher agency in professional learning communities", Professional Development in Education, 2019 Publication	<1%
5	Submitted to Grand Canyon University Student Paper	<1%
6	Deborah Loewenberg Ball, Mark Hoover Thames, Geoffrey Phelps. "Content Knowledge for Teaching", Journal of Teacher Education, 2008 Publication	<1%
7	Submitted to Prairie View A&M University Student Paper	<1%

Appendix G: Letter from Language Editor

20th July 2021

To whom it may concern

EDITING OF DISSERTATION FOR MRS ANDILE PRECIOUS DLAMINI

I have a master's degree in Social Science, Research Psychology and a TEFL qualification from UKZN. I also have an undergraduate and honour's degree Bachelor of Arts in Health Sciences and Social Services from UNISA.

I have 15 years of teaching experience and have been editing academic theses for students from UKZN, UNISA, the University of Fort Hare, and DUT for the past eight years. I have further undertaken editing, transcribing and other research work for private individuals and businesses.

I hereby confirm that I have edited Andile Dlamini's dissertation titled **"EXPLORING TEACHER LEARNING INA MATHEMATICS CLUSTER AS A PROFESSIONAL LEARNING COMMUNITY IN A DISTRICT"** for submission of

her Master of Education in Teacher Development Studies at the University of KwaZulu-Natal**.** Corrections were made in respect of grammar, tenses, spelling and language usage using track changes in MS Word 2013. Once corrections have been attended to, the dissertation should be correct.

Yours sincerely

[redacted]

Terry Shuttleworth (Hons BA Psych Coun, UNISA; Tefl, UKZN; MSocSc Res Psy, UKZN).

DISCLAIMER

Should the student not attend to the changes suggested by the editor and make additions to the dissertation after editing has been completed, the editor cannot guarantee the language, grammar and tenses are correct at the time of publication.