FURTHER EDUCATION AND TRAINING (FET) MATHEMATICS TEACHER PROFESSIONAL LEARNING THROUGH TEACHER ROLES AND ITS INFLUENCE ON PEDAGOGICAL PRACTICES IN ONE DISTRICT IN EASTERN CAPE PROVINCE

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DECLARATION

This thesis is my original work unless otherwise indicated in the text. The work has not been presented for any degree in any other university before.

In instances where the work of others has been used it has been acknowledged accordingly.

This study was mandated by an Ethical Clearance issued by the Durban University of Technology Institutional Research Ethics Committee.

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ABSTRACT

Mathematics, like science, technology and engineering, has been given a prominent position in the school curriculum to promote Science, Technology, Engineering and Mathematics (STEM) industries vital for economic growth and employment creation. However, in South Africa, mathematics education in secondary schools has been in a crisis regarding matric learner failure and this has been blamed on teacher content knowledge gaps. Learners across all education phases have performed poorly in international and national assessments. While research has been undertaken, questions around how mathematics teachers learn and develop in their roles have not been adequately answered. An understanding of these issues is critical.

The purpose of this study was to explore FET Grade 12 mathematics teachers' professional learning through their teaching roles, the kinds of professional knowledge that they gain and how the learning influences their pedagogical practices.

Through a qualitative case study located in an interpretive paradigm, a purposive sample of 26 FET Grade 12 mathematics teachers in a CHE District in the South African Eastern Cape Province provided data through focus group discussions and individual face-to-face interviews, complemented by photo-elicitation. Manual data analysis employed a Six-Step coding process.

Two theories – the triple lens and the mathematical knowledge for teaching – were used to unpack and understand data, and explain findings. Professional learning of FET Grade 12 mathematics teachers through teaching roles emerged in interaction and collaboration during formal, non-formal and informal spheres of action within the school and in wider professional sites. The learning was generally prompted by a combination of personal, occupational and social domains of influence and facilitated through the transmission, transitional and transformative strategies. Professional learning occurred through practice and in interaction with colleagues and resources.

Findings indicated that the FET Grade 12 mathematics teachers gained professional knowledge of general pedagogy, content, pedagogical content knowledge, knowledge of learners and teaching attributes. This study discovered that professional learning influenced FET Grade 12 mathematics teacher confidence in lesson delivery, creativity, communication of facts and concepts, content mastery, general pedagogy, learner discipline and management of resources.

The study also established that FET Grade 12 mathematics teachers were generally reluctant to attend workshops and seminars. Given that most professional learning occurs in interaction, instructional leaders need to increase opportunities for teacher interaction and make workshops and seminars more interactive to develop and inculcate teacher interest in these in-school and out-of-school professional learning gatherings.

With regard to mathematical knowledge for teaching theory, findings revealed that albeit useful for analysing and explaining subject matter knowledge and pedagogical content knowledge, this theory was insufficient on its own as it excluded other knowledge domains, like general pedagogical knowledge and knowledge of learners, which emerged in my data. I, therefore, had to draw on conceptual frameworks. My thesis, therefore, argues for an additive model to mathematical knowledge for teaching theory, which includes all the common domains of professional knowledge to expand the framework and deepen its applicability specifically in trying to understand professional learning issues. The thesis, therefore, suggests the need for more studies, drawing on the framework and developing it to determine its applicability beyond this particular inquiry.

DEDICATION

This study is affectionately dedicated to my late father Rev. Shodias Hwariba Shoko, my mother Alima Shoko, my lovely wife Nokuthula M. Shoko, daughter Tinevimbo Nontokozo Shoko and son Tokudzashe Bonginkosi Shoko. I drew inspiration, determination and perseverance from all of you to complete this journey.

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ABBREVIATIONS

ACE	-Advanced Certificate in Education
ANA	-Annual National Assessment
BSPZ	-Better Schools Programme Zimbabwe
CAPS	-Curriculum and Assessment Policy Statement
CHAT	-Cultural Historical Activity Theory
CA	-Consistency Accuracy
CK	-Content Knowledge
CPD	-Continuing Professional Development
CPTD	-Continuing professional teacher development
DBE	-Department of Basic Education
DRT	-District Resource Teacher
EC	-Ethical clearance
ECDoE	-Eastern Cape Department of Education
EFA	-Education for all
FET	-Further education and training
FGDs	-Focus Group Discussions
FF Interviews	-Face-to-face interviews
GET	-General education and training
GPK	-General Pedagogical Knowledge
HSRC	-Human Sciences Research Council
IMU	-International Mathematics Union
IQMS	-Integrated quality management systems
IREC	-Institutional Research Ethics Committee
KC	-Knowledge of Contexts
KOL	-Knowledge of Learners
MATIP	-Mathematics Teachers In-service Programme
MKT	-Mathematical Knowledge for Teaching
MSI	-Mathematics and Science Infinity
NCLB	-No Child Left Behind
NCS	-National Curriculum Statement

NPDE	-National Professional Diploma in Education
NSE	-Norms and Standards for Educators
OBE	-Outcome Based Education
PCK	-Pedagogical Content Knowledge
PEI	-Photo-elicitation interviews
PGDE	-Post Graduate Diploma in Education
PISA	-Programme for International Student Assessment
SACE	-South African Council of Educators
SACMEQ	-Southern and East African Consortium of Monitoring Educational Quality
SADC	-Southern African Development Community
SADTU	-South African Democratic Teachers Union
SCK	-Specialised Content Knowledge
SDG	-Sustainable Development Goals
SMK	-Subject Matter Knowledge
STEM	-Science Technology Engineering and Mathematics
TDS	-Teacher Development Summit
TIMMS	-Trends in International Mathematics and Science Studies
UK	-United Kingdom
UNESCO	-United Nations Education Scientific Cultural Organisation
USA	-United States of America

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION TO THE STUDY

Introduction

Reforms in education have brought about challenges in the teaching and learning processes in schools globally. The UNESCO Teacher Policy Development Guide (2015), developed at the World Education Forum in Korea in May 2015, outlines priorities for a common education agenda within sustainable development goals (SDGs) for the next fifteen years (2016 to 2030). The organisation pushed for Goal 4 of the SDGs which is to "Ensure inclusive and equitable quality education and [to] promote life-long learning opportunities for all." The document provides a framework for member states to "Ensure that teachers and educators are empowered...motivated, encouraged and supported within well-resourced, efficient and effectively governed schools to engage in on-going professional learning and development" (UNESCO 2015: 21). It proposed not only regular, organised and structured learning but also informal and non-formal continuing professional learning for teachers to promote their teaching effectiveness and motivation towards work (Bourn et al. 2017). The organisation suggested that teacher professional learning be school-based, practice focused and integrated with teachers' everyday work to improve education quality. In this regard teacher professional learning was to be promoted and encouraged within teacher working contexts as it provided opportunities for professional growth and effectiveness. Given these global concerns and attention, an attempt to develop a little more understanding of these important issues became worthwhile, prompting questions around the extent to which professional learning was practised and realised at local levels and how it influenced classroom practice.

The Southern African Development Community (SADC) protocol on education (2015) highlighted the engagement and promotion of both collaborative and individual professional learning for a sustainable future. The advent of education for all (EFA) policy in Africa (1980-1990) caused a multiplicity of problems in the education systems for a number of countries (Mugisha et al. 2014). The problems included lack of appropriate infrastructure, resources, teacher expertise, and teacher quality and quantity. Consequently, teacher education and development reforms in the form of continuing teacher professional learning in formerly neglected subjects like Mathematics and Reading in secondary schools were introduced (Nakabuyo et al. 2011). The EFA reforms suggested a panacea for the challenges leading to inevitable changes in content, methods and approaches to teaching. As a result, teacher professional learning became paramount to update, develop and broaden teacher knowledge and skills for classroom practice (Mulkeen 2007).

Diop (2015) reported that studies indicated that Sub-Saharan Africa faced two key issues – the quantity and quality of teachers – and that addressing these challenges required teacher pre-service, in-service and continuous professional learning. SADC countries have been encouraged and supported to facilitate teacher continuous learning to promote teacher professional learning for improved teacher competence in member states (Nakabuyo et al. 2011). The International Mathematics Union (IMU) (2014) also identified lack of qualified personnel and brain drain as some of the problems that affected the professional learning of mathematics teachers. This led to a new emphasis on continuing teacher professional learning through face-to-face in-service training programmes, starting in Morocco. This was perceived as critical for improving and updating teacher mathematics knowledge and skills. Kyeyune (2014) explored how continuing teacher professional learning impacted the practice of mathematics teachers in Ghana, Kenya, Mali, Senegal, Tanzania and Uganda and discovered that there was a gap in knowledge among mathematics teachers. Against all the above, questions regarding how FET Grade 12 mathematics teachers in the South African context engage in continued professional learning, what they learn and whether their learning influences their classroom practices needed to be answered.

Teacher professional learning is viewed as the means towards teachers' professional development and professionalism in their roles (Cochran-Smith and Lytle 2001). Teachers need to engage in on-going professional learning to keep themselves abreast of knowledge, curriculum and policy changes in schools (Muijsa et al. 2014). Professional learning does not only prepare teachers for new policy changes but also enhances effectiveness and teaching quality (Clarke and Hollingsworth 2002). Consequently, this may enhance the quality of education as a whole. Professional learning is fundamental in developing teacher capacity in the selection and interpretation of curriculum materials and their suitability for learner levels (Borko 2004; Kazima et al. 2008). It is, thus, the hope that developing nations have, for a sustainable educational quality (Stoll and Louis 2006) because it improves teacher effectiveness and enhances learner performance (Hurrell 2013).

Cole (2012) defines professional learning as the benefits gained from attending professional development programmes (workshops, conferences, meetings), sharing experiences by teachers themselves and individual initiatives. However, Bertram (2014) says professional learning does not prescribe how learning is organised but determines the context in which it should occur. In other words, professional learning does not only occur in planned, structured and organised platforms. Cole (2012) presents professional learning more like a means to professional development when he refers to professional learning as 'what happens' in professional development programmes. However, from these definitions, professional learning in this study portrays the situation in which it occurs, and the benefits thereof, emanating from teacher personal factors, workplace factors and outcomes of practice. The process is influenced by external factors in the form of sources of support and information and resource availability within and outside their schools, informally or non-formally.

Background

The South African Policy Context

The South African National Development Plan of 2012, a blue print for a better tomorrow, emphasised the importance of Mathematics in achieving the country's vision of scientific and technological development (Buthelezi 2012). However, the education system has not been on pace with the changes to provide alternative solutions for teachers to meet their new obligations. Buthelezi (2012: 2) further noted that, "the prevailing deficiencies in the basic Mathematics and Science education has become a major constraint in ensuring that the human capital is fully aligned to the country's economic growth and development goals." This concern has triggered a constant demand for teacher professional learning so that teachers can cope with the reforms and the subsequent classroom challenges (Villegas-Reimers 2003).

When democracy was achieved in South Africa in 1994, several radical reforms structurally, socially and in the curricular were introduced in the education system. "The introduction of Outcome Based Education (OBE) and Curriculum 2005 (C2005) was an unprecedented curriculum reform in the history of South Africa" (Ono and Ferreira 2010: 59). This OBE and C2005 reform created a huge gap between its aims and what the majority of teachers were trained for (Jansen and Taylor 2003). Such a gap and many others were major concerns in the South African education system for which there was a need for solutions. It is argued that

OBE was different from previous practices and, therefore, intensive and extensive professional learning and development was necessary to prepare teachers (Fiske and Ladd 2004). However, the training of teachers for OBE was far from adequate (Jansen and Taylor 2003). This was supported by Steyn (2008) who advised that for the education system to be transformed, South African teachers needed to be appropriately equipped to meet the policy delivery challenges in the classroom. Instead of mounting a costly and complex series of professional learning programmes, the Department of Education (DoE) introduced ‘multiplier’ cascade models of teacher training (Ono and Ferreira 2010). This was unsuccessful as some district trainers did not understand the curriculum and, consequently, distorted crucial information (Fiske and Ladd 2004; Mukeredzi 2009). As a result, the training did not translate into desired changes in teacher practices in their classrooms. Meanwhile, Villegas-Reimers (2003) viewed professional learning and development as basic and critical in implementing educational reforms. SADTU (2017: 3) reported that the ‘teacher development summit (TDS) of 29 June – 2 July 2009’ resolved that a new national strategic teacher professional learning plan be developed for the period 2011 – 2025 to curtail teacher shortcomings in their roles.

As alluded to earlier, the introduction of several educational reforms structurally, socially and in the curricular (Stevens, 2005) created challenges that continued to compromise learner performance. These reforms included the Norms and Standards for Educators (NSE) act, Integrated Quality Management Systems (IQMS) and Continuing Professional Teacher Development (CPTD).

A national framework of teacher education programmes was established through a committee of experts in 1995 (Human Sciences Research Council (HSRC) South Africa 2006). The framework was published and scheduled for discussion in 1998 and later gazetted as the Norms and Standards for Educators Act (NSE) in 2000 (Republic of South Africa Department of Higher Education and Training 2010). Its aim was to produce a knowledgeable, highly skilled and valued teacher, better placed to implement the developed C2005, and was deemed to be a strategy for teacher professional learning, recruitment, and retention (HSRC SA 2006). The aim would be achieved through teacher education where teachers graduated with a four-year Bachelor of Education degree and/or a three- year National Professional Diploma in Education (NPDE). The seven prescribed roles of an educator in the NSE were:

- Specialist in a phase, subject, discipline or practice;
- Learning mediator;
- Interpreter and designer of learning programmes and materials;
- Leader, administrator and manager;
- Scholar, researcher and life-long learner;
- Assessor; and
- Community, citizenship and pastoral model (Republic of South Africa Department of Higher Education and Training 2010: 51-52)

The NSE policy, thus, seemingly provided teachers with guidelines to design and implement their professional learning programmes. However, research (Venkat and Spaull 2007; Pournara et al. 2008; Janesen 2012 and Taylor 2013) indicates that teachers remained incompetent and unable to perform effectively, particularly in mathematics.

Following the failure of the NSE to develop the envisaged teacher through this and other policies, a new initiative was proposed: Integrated Quality Management Systems (IQMS). IQMS is an education policy initiative founded on Schedule 1 of the Employment of Educators Act No. 76 of 1998 which empowers the Minister to develop performance standards for educators (Education Labour Relations Council 2003). The policy initiative resulted from research on best practices and consultation with stakeholders in education in 2001 and was signed into law in 2003. The policy was based on the approach that:

- Performance of educators is the foundation of achieving the goal of increased learner achievement;
- Evaluation of programmes and practices is essential to any on-going effort to improve any profession; and
- Evaluation is not apart from but is a part of the education process. (Report to the portfolio committee on (IQMS) 2006).

The objective of this policy was to provide a framework for educational change and performance appraisal standards and processes for educators and was pinned around the principle that performance improvement is a product of personal growth for teachers (Education Labour Relations Council 2003). The policy set a criterion for performance appraisal for teachers which in turn identified teacher professional learning and development needs and proposed necessary training for teachers in order to improve in their roles

(Education Labour Relations Council 2003). IQMS links teacher performance to salary progression according to scores one obtains from appraisal and evaluation processes.

Consequently, its implementation met with resistance as teachers blamed it for abuse by evaluators. Mosope and Pilane (2014:1) revealed that “the weakness of integrating development with appraisal is it leads to the neglect of development in favour of appraisal which is linked to incentives”. Notwithstanding that teachers should engage in professional learning established from appraisal processes, teachers often met to complete associated salary increments forms. Queen-Mary and Mtapuri (2014: 1) also say, “Blatant cheating threatens the system …resulting in teachers losing confidence in IQMS”.

Another initiative, Continuing Professional Teacher Development (CPTD) is a South African Council of Educators (SACE) initiated teacher professional learning programme. SACE is a recognised body for educators, entrusted with the responsibility to register all educators, manage professional learning and development for educators and instil a code of ethics among educators (Mokgalane 2019). The CPTD programme was approved in 2012 but only implemented in 2014. The programme was launched to help promote and organise teacher professional learning and so develop them professionally. The policy enshrined the following responsibilities: providing CPTD workshops in schools; approving quality and credible professional learning providers; endorsing good quality professional learning activities and programmes; allocating points to endorsed activities; and accrediting each educator’s CPTD account (Steyn 2017).

The CPTD programme threatens to deregister a teacher if they do not accumulate the prerequisite 150 points in a three-year cycle (Mokgalane 2019; SACE 2013). Associating professional learning with monetary incentives puts teachers under pressure to professionally learn or to cheat the system in order to financially benefit (Mosope and Pilane 2014). Roux (2018) reported that teachers were getting frustrated by lack of variety in professional learning activities and lack of opportunities to decide on what they should do for their professional learning. From the various policy initiatives for promoting teacher professional learning established by the South Africa education system, whether teachers in general or FET Grade 12 mathematics teachers in particular experienced professional learning through these policy avenues needed to be investigated.

The context of teaching and learning Mathematics in South Africa

The legacy of apartheid perpetuated inequalities in the education system which led to a lack of provision of basic facilities for the teaching and learning of mathematics in black secondary schools. Vewoerd (1953) then Minister of Native Affairs, presenting an Education Bill in parliament (in Khuzwayo 2000: 310) said, “What is the use of teaching the Bantu child mathematics when it cannot use it in practice?” Khuzwayo argues that the apartheid system lacked zeal to support teaching and learning of mathematics and created negative attitudes to the subject among both black teachers and learners resulting in poor learner performance. However, researchers in mathematics education (Van den Berg, 1978; Wilkinson, 1981; Steyn 2008 and Schleicher 2017) indicate that developed mathematics teachers’ in-service training (MATIP) gave hope of improvement in the teaching and learning of mathematics even in black schools but with little impact due to limited political will.

Mathematics education in secondary schools in South Africa has always been in crisis with respect to learner failure rates at matric level since the apartheid era (Khuzwayo, 2000). Taylor (2012) and Spaull (2013) identify a crisis in mathematics teacher content gaps and incompetences at various phases in the school system which leaves the South African education system grossly inefficient and severely under-performing. These views seem to suggest that teachers contribute to poor learner performance at the matric level. Spaull further notes two distinct types of schools: schools for the wealthy (enrolling 20-25% of learners) which achieve high scores and schools for the poor (mostly black schools, enrolling 75-80% of learners) whose performance is abysmal. The two types of school separate learners according to wealth, socio-economic status, location and language (Chen et al. 2020) which creates an anomaly that depicts the survival of the apartheid era policy. Despite teacher incompetence, low levels of learner performance in mathematics in black schools and disparities in resource allocation, the apartheid government never made any attempts to intervene and correct the anomaly.

The teaching and learning of mathematics in South Africa were faced with content and pedagogical challenges. From 2009, across all the school educational phases, South African children have performed poorly in international and national assessments (Trends in International Mathematics and Science Studies (TIMSS); South-eastern African Consortium of Educational Quality (SACMEQ); National Senior Certificate (NSC) and Annual National Assessment (ANA); (Spaull 2013). Research has also indicated appalling levels of teacher incompetence in mathematics teaching (Venkat and Spaull 2007; Taylor 2013). Further, curriculum delivery reflected content knowledge, pedagogical knowledge and pedagogical content knowledge gaps (Jansen 2012; Taylor 2013).

The changes in curriculum policies from the old national curriculum statement (NCS) to the new NCS curriculum and assessment policy statement (CAPS) also appear to worsen learner performance in FET Grade 12 mathematics nationally but in the Eastern Cape province of South Africa in particular. In the past four years the Eastern Cape province has ranked last in national senior certificate (NSC) examinations. During the period 2013-2016, in the CHE district which is the setting for this study, the matric national pass rate remained well below 40% (DBE, 2016). The district was mainly composed of Quintile 1 schools which lacked adequate facilities and resources necessary for effective teaching and learning of mathematics. This was compounded by the fact that the surrounding communities were generally poverty stricken and could not pool resources together to support school improvement. The table below gives a synopsis of Grade 12 mathematics results analysis just before I undertook this study, based on the current CAPS curriculum where the minimum national pass mark was 30%.

Table 1.1: ***CHE District National Matric Results***

Year	No. wrote	No. Passed	No. Failed	% Pass	% Fail
2013	1065	397	668	37,3	62,7
2014	987	329	658	33,3	66,7
2015	1486	486	1003	32,5	67,5
2016	1563	532	1031	34,04	65,96

Source: DBE (2016: 32)

The CHE District matric results reflected in Table 1.1 above were based on national figures. The poor learner performance above shows a deteriorating pass rate, but with a 1, 9% improvement in 2016. The emphasis on mathematics presented an obligation to the South African education system to exert unequivocal pressure on teachers' on-going professional learning in mathematics to effectively equip learners with appropriate knowledge and skills for active participation in the national economy.

However, Kelly (2006) suggests that teachers in the classroom draw from two kinds of professional knowledge: 'knowledge-of-practice' and 'knowledge-in-practice'. Knowledge-of-practice is the explicit knowledge gained from formal university education which is located psychologically within the individual's mind, in this case, the teachers' knowledge of mathematics or of mathematics pedagogical approaches. Knowledge-in-practice is the professional tacit knowledge which does not reside at a psychological level but is rather distributed across and gained from other teachers, students and both conceptual and physical resources like books and computers. It is the knowing-in-practice, a dynamic process resulting from the interactions with teachers, students and resources, within and outside their schools and from teacher reflections on classroom experiences in the contexts of their roles, that is the focus of this study.

The teachers investigated in this study were qualified Grade 12 mathematics teachers. Investigating them enabled an exploration of issues that intersected with the bigger debates on on-going teacher professional learning and development. Further, given that mathematics is fundamental for many professions, in particular science, technology and engineering, it provides opportunities for better career choices for learners. The subject is also key to national and international development through STEM industries (Macnab et al. 2012). Complementing the idea, Abrahams (2015) argues that the world we live in is rapidly changing and mathematics and science are at the forefront of that change. Other researchers in Australia, USA and Britain (Macnab et al. 2012; Burges 2011; Vorderman et al. 2011) further argue that in the world of today, the demand for mathematical skills is increasing so that people may cope with the rapid changes in technology. It is also generally observed that numerical skills are valued and essential in most sectors of society where the use of statistics, and probability are integral to a variety of tasks such as costing, risk assessment, quality control and problem-solving (British Academy 2012; Hodgen and Marks 2013; Vorderman et al 2011). The world, therefore, concurs that, "science, technology, engineering and mathematics (STEM) industries are becoming increasingly central to economic competitiveness and growth, and would provide many of the jobs of tomorrow for young people" (Macnab et al. 2012: 4). Thus, developing an understanding of FET Grade 12 mathematics teacher on-going professional learning to improve mathematics teaching and learning is vital.

Given that the phenomenon of teacher professional learning has become an international concern as alluded to above it, therefore, becomes imperative to focus local efforts in this direction. While these teachers are not fully representative of all FET mathematics teachers due to philosophical orientations and assumptions and the small sample size, they exemplify Grade 12 mathematics teachers teaching in South African settings and may, thus, shed light on issues that are pertinent to the wider context. This study, therefore, seeks to explore the nature of FET Grade 12 mathematics teacher professional learning through their teaching roles and the kinds of professional knowledge that they gain and how that knowledge influences their practice.

Following this introduction, background and context, the focus and purpose of the study is discussed. Subsequently, I discuss my personal context and motivation for the study, axiological assumptions and the rationale behind this study. This is followed by research questions which the study seeks to answer. The overviews of theoretical frameworks and the research design and methodology are then discussed before the chapter conclusion and thesis layout.

Focus and purpose of the study

Notwithstanding that teacher professional learning has occupied the centre stage in international, regional and local debates, (UNESCO 2015; World Education Forum 2015; SADC Protocol on Education (2015) International Mathematics Union (IMU) 2014), questions around how teachers learn through teaching roles have not been adequately explored. Teaching roles in this study are perceived as what teachers engage in during their day-to-day activities and processes in the facilitation of student learning. This study, therefore, aims at developing an in-depth understanding of qualified FET Grade 12 mathematics teachers professional learning through teaching roles in a CHE District in the Eastern Cape Province.

The South African schools' education system is divided into two stages of learning: the general Education and Training (GET) stage (Grades R to Grade 9) and the Further Education and Training (FET) stage (Grades 10 to Grade 12) (SADTU 2019; DBE 2010). The GET stage is further divided into phases: Foundation Phase (Grades R to Grade 3); Intermediate Phase (Grades 4 to Grade 6); Senior Phase (Grades 7 to Grade 9) and then FET. The FET stage/phase forms a conduit to higher education. Thus, the FET stage constitutes the highest school learning level and is a transitional stage into higher education. It is the FET Grade 12 mathematics teachers whose professional learning this study sought to investigate.

Unlike formal learning, learning through teaching roles focuses on the learning process for the individual (Stavenga de Jong et al. 2006). This learning needs no teacher as it is mainly a knowledge construction process of the individual's experience in their role as a teacher. Russell (1988) discovered that an effective strategy to professionally learn is through hands-on experiences in performing teaching roles and practices. It was also noted that teaching roles and practices shape the meaning, and the relationship between theory and practice makes two alternate segments of a single activity (Mukeredzi 2013). This study, therefore, focused on FET Grade 12 mathematics teacher learning in their practices as teachers.

Professional learning through teaching roles may be viewed as informal or life-long learning which is contrary to formal learning or non-formal as it is unstructured and takes place without any clear goals or set objectives because it is often unplanned and self-directed by the learner (Eraut et al. 2004; Mukeredzi 2020). Professional learning and development at school level through teaching roles, according to Mukeredzi (2013), may occur through four domains of formality and experience: formal, which is credit-bearing and bankable, institutionally supported and contributing towards a qualification; experiential (by doing) which is through classroom practice; non-formal, which may be planned, organized and structured either internally or externally to the school but without direct contribution to a qualification; and informal, the incidental professional learning which would be picked up from collegial interactions during, for example, photocopier or corridor chats. However, in this study, given that participants were practicing teachers who were not necessarily engaged in formal learning programmes, this study set out to understand only three dimensions: experiential; non- formal; and informal experiences of their professional learning. Thus, the purpose of this study was to develop an in-depth understanding of what these teachers go through in their experiential, non-formal and informal professional learning and how this learning impacted their classroom practices. I tried to get behind FET Grade 12 mathematics teachers' 'faces and skins' (Bhengu 2005) to understand, through their eyes and stories (Mukeredzi 2009) their professional learning experiences in their roles. Data generation, therefore, attempted to elicit responses indicating whether or not, and to what extent, some or all of these dimensions benefited professional learning of these FET Grade 12 mathematics teachers.

Further, Billet (2001) and Le Clus (2011) concur that classrooms, schools and wider professional sites are effective spaces for on-going professional learning of knowledge and skills as teachers can marry theory to practice realistically and efficiently. Such learning, according to Le Clus, includes experience-based learning in the classroom, structured learning within and outside the school and incidental, informal learning.

Mukeredzi (2013:1) also discovered that teacher professional learning through teacher roles revolved around aspects of “pedagogical knowledge (PK), content knowledge (CK), pedagogical content knowledge (PCK) and knowledge of context” (KC). Villegas-Reimers (2003) adds that knowledge gained represents professional growth of the individual and suggests that teachers can be active learners in their roles. Such learning occurs outside formal activities (learning) when one is performing either core or non-core functions of being a teacher (Mukeredzi 2009). It was, therefore, also the purpose of this study to investigate what kinds of knowledge these FET Grade 12 mathematics teachers professionally gain in their roles.

Yan (2009) considers teachers’ professional learning as one of the factors influencing teacher practices as it can change teachers’ educational background, personality and mastery of subject matter through experience, resulting in shifts in teaching methods in the classroom. Thus, this study also wanted to establish how the FET Grade 12 mathematics teachers learning influences the manner in which they approach their work as mathematics teachers.

Personal context and motivation

To provide a picture of my positionality in this study I discuss my personal context and motivation by illuminating my interest and what attracted me to this study. Korstjens (2017) points out that the personal context provides variety that enables understanding the descriptions, explorations and explanations of phenomena. Thus, the story of my professional life is intended to help readers to understand my context.

My professional journey shapes my perceptions, attitudes, understanding, opinions, values and norms that distinguish me as a mathematics teacher. I embarked on this study employed full-time as a FET mathematics teacher in the DBE in the Eastern Cape Province of South Africa. I was teaching FET mathematics Grades 10 - 12. At the time, all Grade 12 teachers in the province were compelled to engage in mathematics content gap intervention programmes which were initiated and organised by the Eastern Cape Department of Education (ECDoE) and run by Nelson Mandela University. The programmes taught mathematics teachers topics in the new CAPS document (the syllabus for FET mathematics). Through this experience, I realised that teachers are custodians of curriculum delivery in schools. Teacher knowledge and pedagogical practices are, therefore, paramount for successful curriculum delivery. I appreciated the need to engage in on-going professional learning to keep myself abreast of knowledge, curriculum and policy changes (Muijsa et al. 2014) in order to effectively perform my teaching roles, given that professional learning is viewed as a basic and fundamental aspect for successful learner performance (Villegas-Reimers 2003).

My career as a teacher began in Zimbabwe when I completed a Diploma in Education programme at the United College of Education in Bulawayo. I taught in the primary school for five years and then moved to the high school as a mathematics teacher. Having experienced teaching mathematics in both primary and secondary sectors, I developed a passion for the subject and felt challenged to excel in it. It became clear to me that knowing mathematics and knowing how to teach mathematics were two different aspects, contrary to the general perceptions that they were the same. I later got a job as a District Resource Teacher (DRT) with the Better Schools Programme Zimbabwe (BSPZ) where my role was to organise and run in-service professional learning and development programmes for teachers in the district. This made me understand the value of and kept me close to teacher professional learning and teacher professional learning needs. Mathematics and science subjects were foregrounded and aligned with national development goals and most of the in-service professional learning and development programmes targeted mathematics and science teachers.

These experiences as a mathematics resource teacher also kept me exposed to teacher professional learning, and teaching of mathematics which further fuelled my interest in the discipline and in teacher learning. After a few years I moved into teacher education as a lecturer in a teacher's college where I taught Professional Studies and the teaching of mathematics. As a teacher educator one of my major roles was supervision of student teacher professional learning and development during teaching practice. This experience further exposed me to the dynamics of mathematics classroom practice and professional learning. Thus, embarking on doctoral studies, I could not have chosen any other area of research outside mathematics teacher practices and professional learning.

As a Grade 12 mathematics teacher in the Eastern Cape Province in South Africa as alluded to above, I later got promoted to Deputy Principal of a high school. As Deputy Principal my job entailed, among other things, standards control and maintenance of academic and professional standards through teacher supervision and monitoring in their teaching roles. All this not only kept me in close contact with teacher learning and classroom practice but also developed in me a passion for teacher professional learning. Thus, my experiences over the years brought me into this study with some axiological assumptions which I will discuss next.

Axiological assumptions

Axiological assumptions relate to what is important and valuable in research which is carried by both the researcher and the researched. In this section I declare my axiological assumptions admitting that research is value-laden in nature as perceived by Lincoln (2011) and Creswell (2003). I was the main instrument for data generation, analysis and presentation and, as such my experiences and biases may have encroached on my study findings.

Participants were Grade 12 teachers who had attended content gap intervention programmes alluded to above. This understanding enhanced my awareness, and sensitivity to the complexities and experiences FET Grade 12 mathematics teachers encountered which was vital when working with them in this study. Through my leadership roles (teacher and deputy principal) I understood the FET mathematics syllabi and I came into the study with knowledge of the structure of the FET Grade 12 mathematics syllabus and mathematics teacher learning through intervention programmes. I, thus, need to declare upfront that in this study I paid particular attention to the teachers' professional learning experiences in their different school contexts. Again, thanks to my awareness of the practices in FET Grade 12 mathematics teaching due to my previous and current experiences, I brought certain biases to this study. Notwithstanding all efforts to ensure objectivity, these assumptions and biases might have influenced my perceptions and expectations of the data that I generated and the manner in which I analysed and interpreted it.

I started this research with the perspective that the FET Grade 12 mathematics teachers have complex and diverse professional learning experiences. This was a significant expectation that I took for granted. I interrogated the nature of their professional learning experiences, the kinds of knowledge that they gained and how the learning influenced their pedagogical practices. Against this, values of participants were explored and analysed through their responses to determine how those experiences influenced their roles, practices and reflections as teachers. I have declared my axiological assumptions upfront. In the next section I discuss the rationale for the study.

Rationale

My rationale is driven by three considerations: mathematics teachers' practice; policy; and gaps in the literature.
To begin with, all teachers are expected to engage in continuing professional learning to remain effective in their roles (DBE 2011). This is because continuing professional learning is central to the process of change and transformation of teacher professional identity (Kennedy et al. 2007). Bezuidenhout (2011: 1076) emphasises the need for continued learning among mathematics educators saying, "Teaching staff should realise that...to become good teachers they also have to undergo training, learning … and stay informed of innovations and trends in education" which points to the need for engagement in professional learning. Teachers should, thus, remain up-to-date and improve themselves by learning the good and professional ways to enhance their knowledge and effectiveness (Guskey 1997). Informed by these arguments, it was vital to develop an in-depth understanding of whether, and how the FET Grade 12 mathematics teachers engaged in professional learning.

Cohen and Hill (2001) report a strong relationship between professional learning experiences and the improvement of teachers' practices. Further, Day and Gu (2007) reiterate that professional learning opportunities must be designed to influence teacher competences and influence learners' performance. Despite this value of professional learning enunciated, teachers themselves are often not aware of the amount of learning that they gain through their roles and responsibilities as teachers. According to Mukeredzi (2020) learning through teaching roles is intricately intertwined in institutional fabrics and contexts. Consequently, it becomes invisible, either taken for granted or not appreciated as learning, and learners themselves (the teachers) are often unaware of such learning and may overlook their own learning. I was aware, however, that some professional learning always took place. It was, therefore, vital to learn about the FET Grade 12 mathematics teachers from themselves – how they experienced learning, what they learnt and how their learning influenced their practice. These experiences would be significant to policies on teacher professional learning generally and to FET Grade 12 mathematics teachers' professional learning in particular.

Secondly, there is limited literature available for decision makers on what FET Grade 12 mathematics teachers experience in their teaching and their professional learning in these communities. The challenges and pressures they endure, as well as their experiences related to professional learning in these schools, needed to be understood and documented. These teachers, notwithstanding trying circumstances, are expected to devise effective strategies in handling learners and the school community at large as they interpret and implement policies and procedures laid down by decision makers. This study, thus, intended to develop an in-depth understanding of what these FET Grade 12 mathematics teachers go through.

In interaction with colleagues in their school communities, regarding their professional learning, these teachers can contribute to policy development, critique and practice in relation to professional learning. Given the location of the study within broad international concerns, findings from the study could inform decision and policy makers, institutions as well as teacher education specialists on professional learning of FET Grade 12 mathematics teachers in schools.

Thirdly, studies conducted globally (Kennedy 2005; Joubert et al. 2010 and Campbell 2016) have focused on how mathematics teachers experience professional learning in schools but apparently overlooked professional learning through wide professional sites. Similarly, regional studies conducted (Kinyota et al. 2019; Komba and Nkumbi 2016) also focused on how teachers engaged in professional learning within their schools and again did not include professional learning within other professional spaces. Regional studies in particular focused on how mathematics teachers professionally learn through various activities in their schools. The national studies (Graven 2002) examined mathematics teacher professional learning through communities of practice. Chirinda and Barmby (2016) examined mathematics teachers professional learning through problem-solving, while Ono and Ferreira (2010) researched science and mathematics teacher professional learning through lesson study. Thus, from the international regional and national studies reviewed, none of the studies investigated professional learning of FET Grade 12 mathematics teachers in their roles which encompassed in-school and wider professional learning sites. Therefore, through this exploration of FET Grade 12 mathematics teachers' professional learning through teaching roles, this study would contribute to filling this gap.

Research questions

Following the issues discussed above, the study intended to investigate FET Grade 12 mathematics teachers' professional learning through teacher roles. To enable in-depth understanding and the achievement of this aim, the study wanted to address the key question: How do the FET Grade 12 mathematics teachers engage in professional learning through their teaching roles and how does the learning influence their pedagogical practices?

This key question was addressed through the following three subsidiary questions:

1. How do FET mathematics teachers engage in professional learning through teaching roles?
2. What kinds of professional knowledge do the teachers gain?
3. In what ways do these teachers say their professional learning influences their pedagogical practices?

Overview of Theoretical Framework

This study was underpinned by two theoretical frameworks: the triple lens (Fraser et al. 2007) and the mathematical knowledge for teaching (Ball et al. 2008). The theoretical frameworks guided data generation, presentation and analysis, as well as offering principles and parameters for operation during the study, like what a plan for a house does for builders. This is emphasised by Lincoln and Guba (1994) who argue that research outside a theoretical framework does not exist.

The triple lens (Kennedy et al. 2007), a three-in-one professional learning theoretical framework, features Reid's quadrants of teacher learning known as 'Spheres of action', Bell and Gilbert's (2005) aspects of professional learning – the 'domains of influence'; and Kennedy's framework for analysis (2005). Reid's quadrants analyse spaces and opportunities in which teacher professional learning occurs. The theory presupposes that teacher professional learning takes place in formal and informal, planned and incidental situations. This was complemented by Bell and Gilbert's aspects of professional learning: personal, social and occupational aspects. Bell and Gilbert emphasise that the teacher's desire to learn is motivated by their personal, social or occupational influences. Kennedy's models describe how teachers experience professional learning in their roles, whether transmissive, transitional or transformative. These three frameworks put together constitute the triple lens theory and, in this study, created a formidable structure which enabled a nuanced understanding of how FET Grade 12 mathematics teachers experienced professional learning in their roles.

The mathematical knowledge for teaching theory (Ball et al. 2008) is a practice-based theory founded on the assumptions that mathematics teaching requires teacher knowledge peculiar to it (Ball 2009; Jankvist 2016). The theory identifies two major forms of teacher professional knowledge in the teaching of mathematics: subject matter knowledge (SMK) and pedagogical content knowledge (PCK). The theoretical framework divides SMK into three forms: common content knowledge; mathematical knowledge at the horizon; and specialised content knowledge. PCK is also divided into three categories: knowledge of content and teaching; knowledge of content and curriculum; and knowledge of content and students. Through these forms of knowledge, the theory enabled understanding and explaining of the kinds of knowledge that FET Grade 12 mathematics teachers learn from their professional learning and how these knowledges influence their pedagogical practice.

Overview of the methodological approach

This study was located in the interpretive paradigm and adopted a case study design which enabled in-depth understanding of the FET Grade 12 mathematics teacher professional learning in CHE district in the Eastern Cape Province. A case study design is a methodology where exploration of the phenomenon is done within a particular context using a variety of sources (Baxter and Jack 2008). The case in this case study was professional learning of FET Grade 12 mathematics teachers through teaching roles, what they learn and how the learning influences their practice. This was a qualitative case study where purposive sampling was used to extract 26 participants who provided data through interviews, focus group discussions and photo elicitation. Data analysis adopted open coding which was accomplished in six stages.

The philosophical orientations and assumptions, design and approach adopted for the study, as well as the sampling designs and data generation techniques employed, limited generalisability of findings and, as such, the choice to transfer findings to other similar situations was left to the reader and researcher, based on their understanding and experiences. However, lack of generalisability may not yield any consequences as proponents of qualitative studies argue that generalising removes the character of a qualitative study which in itself is subjective (Padgett 2008).

Conclusion and overview of the thesis

This chapter commenced with an introduction tapping into big debates on professional learning from reforms made by education systems internationally. Findings from this study would, thus, contribute to these global, regional and local debates.

A discussion outlining the background of the South African policy context in relation to initiatives launched to promote teacher professional learning, as well as the context of mathematics teaching and learning in South Africa, was presented. The focus and purpose were then outlined followed by my personal context and motivation, after which I declared upfront my axiological assumptions. The rationale was then discussed under three underpinnings: theory, policy and the gap in the literature to which the study wanted to contribute. Reviews of theoretical frameworks and methodological approach were then provided, leading to the conclusion.

This thesis is organised into seven chapters. Chapter One set the scene as explained above. The literature review in Chapter Two contextualises the study and illustrates academic work that has been carried out elsewhere globally, regionally and nationally. Through this critical evaluation of related studies carried out, gaps were identified. However, from the critical review none of the studies investigated studied professional learning of FET Grade 12 mathematics teachers through teaching roles and their influence on pedagogical practices. The last part of this chapter presents the theoretical frameworks whose overview has been provided above. Chapter Three provides the research design and methodology where the research paradigm, design, approach and methods used for data generation are discussed. It also covers data analysis, issues of trustworthiness and ethics. Chapter Four presents data presentation and analysis addressing Question One about how FET mathematics teachers engage in professional learning through teaching roles, where it emerged that the Grade 12 mathematics teachers studied experienced learning through in-school and wide professional sites interactions. Chapter Five is another data presentation and analysis chapter addressing Question Two regarding the knowledge that FET Grade 12 mathematics teachers gain from their professional learning. It emerged that the teachers gained common content knowledge, subject matter knowledge, specialised content knowledge, general pedagogical knowledge, pedagogical content knowledge, and knowledge of learners. Chapter Six comprised data presentation and analysis addressing Question Three on the influence of professional learning on pedagogical practices. The teachers' pedagogical practices were influenced by classroom behaviour, classroom communication, management of learner discipline and management of teaching and learning resources. Chapter 7 is the synthesis chapter which draws conclusions and recommendations from the study.

Having introduced the study in Chapter 1, the next chapter reviews related literature.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This study investigates professional learning of FET mathematics teachers through their teaching roles and how the learning influences their pedagogical practices. The previous chapter, the introduction to this research study, delineated the study outlining the background to the study, the problem under investigation and the rationale of the study. This chapter reviews the relevant studies on teacher professional learning in the teaching of mathematics and how it influences pedagogical practices. Professional learning for teachers is important for educational transformation and national development (Kennedy et al. 2005). Developing nations expect that teachers engage in professional learning for capacity building for sustainable educational quality (Stoll et al. 2006). Mathematics teachers, like all other professionals, need to engage in continuous professional learning to gain relevant knowledge and skills for professional growth (McDonald 2014). Given the value of teacher professional learning, a literature review was, therefore, necessary to understand what has been studied on the topic and draw on ideas, concepts, methodologies, findings, styles, challenges and prospects (Benacherine 2019) from related studies, thereby contextualizing the study.

The literature review presents a rationale and logical case founded on a comprehensive understanding of the existing state of knowledge about the topic under study (Kim 2018) that places my study in focus. The literature review fostered a logical trend through past relevant findings on the phenomenon under investigation (Benacherine 2019) and helped me to identify pointers that could help in addressing the intentions of my study. This review of literature also created an insightful landscape for new areas to look out for in my study through scrutinising and evaluating approaches, designs and methodologies used by research experts in earlier studies. This exercise enabled the identification of strengths and weaknesses of the processes used in previous academic work (Rudenstam and Newton 2007) which helped me to place my study in perspective. Thus, a literature review was necessary to understand how other researchers engaged in similar studies and so to benefit from their experiences (Shi 2006). In this regard the review of literature enabled the identification of gaps in prior research to which this study contributed. Arshed and Danson (2015) assert that a literature review helps to build a coherent argument leading to the description of a proposed study. Drawing from this perception, the literature review offered a context upon which I refined, focused and shaped my research questions, as well as theoretical and conceptual frameworks. Again, critically evaluating reviewed studies provoked critical thinking processes (Arshed and Danson 2015) which helped me to recognize the objectives of my study and to avoid replication of earlier studies. Thus, this review process ushered the zeal to embark on my study considering that the purpose of the study was exposed and its contribution to new knowledge envisaged.

I consulted mainly recent sources – journal articles and books on how FET mathematics teachers engaged in professional learning and how the learning influenced their practice. A few dated sources were also incorporated as they contained pertinent information on trends of professional learning of mathematics teachers from 1994 when South Africa attained its independence. This is given that from 1994 the education system in South Africa has been undergoing structural and conceptual changes (Steyn 2008) to mitigate against the adverse policies of apartheid which significantly affected the teaching and learning of mathematics (Khuzwayo 2000; Graven 2013; Jojo 2019).

The literature in this chapter is organised conceptually, drawing concepts from research questions. First, the chapter defines key concepts related to professional learning and its derivatives. This is followed by a discussion and analysis of literature on how teachers engage in professional learning. There follows a discussion of literature around professional knowledge gained through teacher roles. Fourthly, related literature on how the learning influences mathematics teachers' pedagogical practices is analysed.

Understanding the concept of professional learning

A concept is a mentally constructed idea which embodies meanings, beliefs, individual views, propositions and opinions held as truths about terms people use in their work environment (Brown 2004; Sutton 2016; Jordan 2013). This relates to the way individuals understand, perceive and form ideas or impressions (Podsakoff 2016) about things they come across in their roles. In this study a concept is an abstract idea or mental representation of individual mathematics teachers' thoughts about a cluster of related observations in their roles. This section concentrates on deriving an understanding of the concept of professional learning through its derivatives: profession, professional, professionalism, professional learning and finally professional learning for mathematics teachers in particular.

Profession

The concept of a profession has attracted the attention of many workers in different disciplines who generally seek to define it in their favour: teachers, health personnel, engineers and lawyers alike (Collier 2012; Hirsh 2015; Saks 2012; Scherff 2018). A more comprehensive definition which is non-aligned is offered by The Australian Council of Professions (2003:1) which defines a profession as:

> *A disciplined group of individuals who adhere to ethical standards and who hold themselves out as, and are accepted by the public as possessing special knowledge and skills in a widely recognised body of learning derived from research, education and training at a high level and who are prepared to apply this knowledge and exercise these skills in the interest of others.*

This definition identifies adhering to ethical standards, possessing special knowledge and skills, applying knowledge and skills and being accepted by the clientele, as factors distinguishing a profession. In a similar view, Saks (2012: 6) perceives a profession as a disciplined group of individuals “possessing unique and positive characteristics, including distinctive knowledge and expertise”. In these definitions, a profession is construed as comprising a group of people who are associated with one another as a consequence of their related professional identities and abilities. They conceive of a profession as made up of special individuals, knowledgeable and skilled to serve others in their roles. In this study, a profession is a discipline made up of individuals (the FET mathematics teachers) who possess knowledge and expertise and are bound by ethical standards in performing their duties which make them desirable among the people they serve. Ball et al. (2008) in their Mathematical knowledge for teaching theory used as the theoretical framework in this study, identify different kinds of knowledge mathematics teachers require to become professionals in their roles.

Professional

A professional is generally viewed as someone who belongs to a profession and who is characterised by and conforms to the technical or ethical standards of that profession (Zafiropolous 2017). However, scholars perceive a professional in a multi-dimensional approach where the guiding principles are the commitment to serve and the economic gains the profession offers. Friedson (2001) has defined ‘professional’ as a concept that puts greater commitment on expert execution of roles rather than on economic gains: to the quality of performance rather than how the job pays. Thus, people usually refer to the way things happen in the work environment as either professional or not professional, for example, professional teaching, professional football, professional music and so on. This perception about ‘professional’ relates to how processes of duty execution demonstrate the application of expert knowledge and skill, quality and integrity. Other scholars (Professional Standards Council 2017; Ibrahim 2012) perceive a professional as a member of a profession who earns their living from a specified activity and is altruistic in nature. Balthazard (2015: 2) in support of this view conceives a professional as one who puts “doing good work’ and the ‘quality’ of the work ahead of economic gain and the economic efficiency of work. In other words, it is not about money; it is about the quality and integrity of the work.” Balthazard like Friedson agrees that a professional is an individual committed to their work quality and integrity. They also allude to maintaining high standards of performance and efficiency as other attributes of a professional which lead to professionalism. In this study ‘professional’ relates to attributes of FET mathematics teachers in their teaching roles which demonstrate confidence, expert knowledge, efficiency and skill during instructional practices.

Professionalism

Professionalism is generally seen as an attitude whereby individuals participate in a role, commit themselves to that role and consequently deliver services in the role to the best of their effort and ability. Collier (2012: 3) has defined professionalism as “those strategies and rhetorics employed by members of an occupation in seeking to improve status, salary and conditions”. Professionalism, thus, involves doing work according to some set of ethical principles, engaging in effective interactions with the clientele, being reliable and committed to improving one’s competence. Professionalism hence, requires members of the profession to work as a team, reflect on their performances and participate in life-long learning (Villegas- Reimers 2009) so as to remain astute and abreast of the demands of changing contingencies. In this regard professionalism is promoted and sustained through professional learning.

Professional learning

Professional learning is generally assumed to be the means towards teacher professionalism which leads to teachers becoming professional. Barry (2017) understands the concept of professional learning as a teacher-driven continuous engagement which conceives of learning as becoming. Professional learning occurs through formal experiences in institutions and informal experiences, through reflection on their work and collaboration with colleagues (Fraser et al. 2007). Professional learning is also viewed as a platform where teachers learn from both collaborative opportunities and individual experiences that promote the development of skills, knowledge, capabilities and practices in their career. Barry (2017) and Saks (2016) view professional learning as what teachers do to rejuvenate their thinking and professional knowledge and to ensure that their practice is well informed and current. In this regard, professional learning is intended to influence learner-outcomes through improved teacher practices. Scherff (2018) considers professional learning as typically interactive, sustainable and tailor-made to suit teachers' needs in their practices.

Timperley (2020) on the other hand conceives of teacher professional learning as an on-going cycle that begins with schools identifying the educational outcomes they value for their students. In contrast to the definitions above, Timperley's definition portrays professional learning as a school matter rather than an individual teacher matter where the school, through their expectations, determines what teachers must learn. Informed by Rogers (2007: 632) professional learning programmes for mathematics teachers are "an attempt to bring about change in classroom practices of teachers, change in dispositions, beliefs and attitudes and change in the learning outcomes of students." Thus, in this study professional learning is understood as a necessary teacher development on-going activity, deliberately engaged in by FET mathematics teachers to learn more about their work and how they can do it better for the benefit of their learners. This is consistent with Mizell (2010) who asserts that mathematics teachers as professionals often voluntarily seek new knowledge. The affinity for new knowledge among mathematics teachers is propagated by the global view (Matos et al. 2009; Joubert and Back 2010) that professional learning offers opportunities for growth and change through learning in and from practice.

Global perceptions on teacher professional learning

The beginning of the twenty-first century placed learner achievement at the forefront of educational demands across the globe (Wood 2016). Consequently, emphasis on learner achievement led to the “No Child Left Behind’ policy (NCLB 2002) in the USA and in most nations of the world. Hence, individual nations embarked on professional learning to improve the knowledge and skills of teachers in their practices (Wood 2016). The US Department of Education secretary, Spellings (2006: 1), in support of teacher professional learning argued that: “We know nothing helps a child learn as much as a great teacher. … One of the most important factors in raising student achievement is a highly qualified teacher.” Concomitant to this were events in South Africa where on attainment of independence in 1994, teacher education shifted to universities in search of highly qualified teachers to meet quality classroom obligations (Steyn 2008). Globally, research has linked continuing teacher professional learning to teacher effectiveness, teacher adaptation to new innovations and learner achievements (Kraft and Papay 2014; Nilsen and Gustafsson 2016; Granovetter and Soong 1983). The review of literature below critically analyses and discusses how mathematics teachers experience professional learning drawing on global, regional and national debates.

How teachers engage in professional learning through teaching roles.

This section discusses international, regional and national studies which investigated how teachers engage in professional learning. The literature is evaluated and critically analysed in relation to context, focus, theoretical and conceptual frameworks, methodology, findings and recommendations.

Kennedy (2005) in the United Kingdom, examined models of continuing professional development (CPD) for teachers. Kennedy’s study used document reviews and focused on reviewing international literature, taking specific examples from the Scottish context. The study aimed at proposing a framework built around major characteristics of each of the models identified. The study identified nine different models of continuing professional development through which teachers experienced professional learning. Whereas Kennedy examined secondary data, the current study uses empirical data. Kennedy’s (2005) study provides some pointers to look out for regarding the models of professional learning that FET mathematics teachers in the current study engaged in.

Kennedy (2005) discovered that teachers engaged in professional learning which transformed their classroom practices through CPD models: the training model, award-bearing model, the deficit model, the cascade model, standard-based model, coaching/mentoring model, the community of practice model, the action research model and the transformative model. From these models Kennedy (2005) also discovered that teachers' professional learning during classroom practice could be categorised into transmission, transitional and transformative modes of teaching. Consequently, Kennedy categorised the different CPD models into these three and developed a framework for analysis of different models of professional learning that teachers experience in their learning through practice. This pointed me to a theoretical lens that I adopted (the Triple lens theory, Fraser et al. 2007) for data analysis to establish whether teachers in this study experienced professional learning through any of the three modes. Renkly and Bertolini (2018) and Kempen and Steyn (2016), argued that Kennedy's deficit model dealt with teachers professional learning needs 'reactively' rather than 'proactively' and failed to recognise professional learning expectations of competent teachers. Both studies (Kempen and Steyn 2016; Renkly and Bertolini 2018) proposed new research to develop new models of professional learning although they differed in the setting of their proposals. However, while the current research focus and methodology differ from those of Kennedy, the training, deficit and transformative models of professional learning offer pointers to look out for regarding workshops, to determine whether the modes of FET mathematics teacher learning are transmissive, transitional or transformative.

Unlike Kennedy (2005) in the UK, who studied models of professional learning, Joubert et al. (2010), also in the UK, studied professional development of mathematics teachers focussing on professional learning opportunities and change. While I examine professional learning opportunities for FET mathematics teachers, change is outside my study parameters although some references to change comes up in discussions on how the learning influences pedagogical practices. Similar to Kennedy (2005) Joubert et al. (2010) examined different professional learning initiatives through models to understand individual learning initiatives. This was a qualitative case study, which, like my study, generated data through interviews complemented by observations. In addition, I used photo-elicitation and focus group discussions as complementary tools. Joubert's study comprised 250 mathematics teachers in primary and secondary schools and professional learning initiative coordinators. This was a big study compared to my study which drew data from twenty-six FET mathematics teachers. My study adopted the Fraser et al. (2008) triple lens theory to understand and explain how mathematics teachers engaged in professional learning, while a socio-cultural philosophical perspective (Vygotsky 1978) was adopted in Joubert et al.'s study. The socio-culturalist theory suggests that teachers' experiences and contexts have major influences on their learning (McLeod 2014 and Shabani 2016). Joubert et al.'s (2010) study identified thirty professional development initiatives that included the transformative model of professional learning through workshops and meetings with other mathematics teachers run by different providers, in different locations. The study relates to my study insofar as it involved workshops as some of the spaces through which teachers experience professional learning.

The findings indicated that mathematics teachers experienced professional learning through the use of teaching and learning resources, reflection, reading and discussing work related issues with colleagues. Hargett et al. (2018), Lewis and Rebecca (2014) and Kendal (2019) who studied professional learning through resources, concur that exposure to mathematical resources prompts exploration of mathematical ideas and motivates teachers in their learning. The current study also seeks to establish whether resources have an impact on FET mathematics teachers' professional learning. Mathew et al. (2017:126) argue that, "Reflective practice is a process that facilitates … learning and understanding, and it plays a central role in teacher professional learning." In this regard, reflective practice as a teacher's professional learning space serves as a knowledge and skills audit for teachers who in turn seek to fill in identified professional gaps. Joubert et al.'s (2010) study discovered that teachers also learnt from meetings with colleagues and 'stocking up' ideas for trying out in their classrooms. Shah (2012) and Horn (2020) who also studied collegiality in professional learning, concur that colleagues are potential professional learning resources. Informed by these authorities, this study also tries to establish whether collegial resources were a vital element for FET mathematics teachers' professional learning. However, related studies by Koebele and Harris (2019) and Barton and Stepanek (2012) indicate teacher reservations regarding professional learning from colleagues due to fear of exposing ignorance. The study by Joubert et al. (2010) also reported professional learning of mathematics teachers through teaching gap tasks to learners and discussing gap tasks with colleagues. This study also tries to establish whether FET mathematics teachers experience professional learning through content gap discussions with colleagues. Joubert et al.'s findings further indicated that professional learning occurred through learning from experts who in turn helped the teachers to link theory to practice.

Another study by Shakrchy and Jansson (2021) examines Professional learning of newly arrived teachers in Sweden. Unlike Kennedy and Joubert et al. above, the study focuses on 'Fast-Track' developing migrant teachers in pre-school teacher programmes. The Fast-Track programme is simply a quick initiation programme of migrant teachers into the Swedish education system and curriculum before they can be absorbed as teachers. Shakrchy and Jansson aimed at investigating how participants in the Fast-Track programme engaged in professional learning. The study uses qualitative and quantitative approaches separately to generate and analyse data as opposed to my study which uses only the qualitative approach. There were 1100 participants used in the quantitative study while 18 participants were used in the qualitative study to gather deeper understanding of how these teachers experienced professional learning. Questionnaires and interviews were used for generating data and the human and social capital theory employed to analyse data as opposed to the triple lens theory applied in the current study.

Shakrchy and Jansson (2021) found that migrant teachers engaged in professional learning during lectures, seminars, group work, group discussions and individual study projects. Similar to Joubert et al.'s (2010) study, these teachers experienced professional learning through experts during lectures and seminars. They also learnt through interaction during group work, group discussions, as well as individual effort during individual study projects. Learning from experts guarantees professional learning of expected knowledge, values and procedures of a system although sometimes the experts are hindered by problems of semantics and characteristics of expertise which tend to differ with contexts (Berliner 2001). This prompted me to explore how FET mathematics teachers engaged in professional learning from their association with experts in their settings. Proponents of learning through interaction (Slatter 2004; Poth 2018; Hayes 2016; Torrey et al. 2016) argue that individuals depend on each other for their own learning and work and that teachers are better together. Brown (2019) urges teachers to interact with one another while explaining that education has complex issues that are difficult for individual teachers to tackle by themselves. Drawing from these ideas, the current study sought to explore how FET mathematics teachers experienced learning from their interactions as colleagues.

Shakrchy and Jansson (2021) also discovered that migrant teachers engaged in professional learning during internships. Internship relates to professional learning the migrant teachers experienced from one-to-one support realised when they worked in collaboration with local teachers (Shakrchy and Jansson 2021). Internship opens channels for on-the-job learning which stimulates professional growth and professionalism (Balthazard 2015; Collier 2012). This relates to Kennedy's (2005) model of coaching and mentoring. The study found that the teachers also engaged in professional learning during bonding and bridging social barriers. This was when the migrant teachers mixed with local teachers to understand the norms and values of the Swedish society so as to be able to relate to the context appropriately. This finding helped me to explore how FET mathematics teachers engage in professional learning through social gatherings, during sports and community functions.

Unlike Kennedy (2005) and Joubert et al. (2010) in the UK who studied models of professional learning and professional learning opportunities for mathematics teachers respectively and Shakrchy and Jansson (2021) who studied professional learning of migrant teachers in Sweden, Campbell (2016) in Canada studied the state of teacher professional learning in Canadian schools. The study adopted a mixed methods approach contrary to my study which was purely qualitative and employed multi-modal approaches to data generation (focus group discussions, face-to-face interviews, and photo-elicitation). Campbell's study generated data through focus group conference calls, interviews and reviews of professional learning articles.

Campbell found that professional learning was motivated by teachers' learning needs, experiences, interests, contexts and career stages. This finding showed that teacher professional learning is influenced by individual teachers' personal, social and occupational aspects (Fraser et al. 2007). The personal, social and occupational aspects prompted me to adopt the triple lens theory for analysing how FET mathematics teachers engaged in professional learning through teaching roles. Campbell's study also discovered that mathematics teachers engaged in professional learning through collaboration. Musanti and Pence (2010) and Darling-Hammond and Bransford (2005) concur that teacher professional growth does not happen in isolation: rather, teachers engage in meaningful learning through collaborating with one another. Darling-Hammond and Bransford further noted that collaboration promoted team work and an understanding of purpose which helps individuals to feel safe to take risks in their practice. In this study I also tried to establish whether any professional learning occurred through collaboration. However, Miller (2020) warns that common understandings through collaboration should not lead to 'common of everything' which may stifle innovation and creativity among teachers. Campbell's study confirmed earlier studies by Timperley (2008) who observed that teachers needed access to multiple and varied opportunities to professionally learn new content, gain insights and be able to apply new understandings in their practice in collaboration with colleagues.

The international studies by Kennedy (2005) and Joubert et al. (2010) in the UK, Shakrchy and Jansson (2021) in Sweden and Campbell (2016) in Canada indicated that there were varied spaces through which teachers experienced professional learning. The studies used qualitative approaches, except for Campbell and Shakrchy and Jansson who adopted mixed methods. Whereas Kennedy (2005) in the UK and Campbell in Canada studied how teachers generally engaged in professional learning, Joubert et al. (2010) particularly studied professional learning for mathematics teachers irrespective of Grade. Unlike the other three studies, Shakrchy and Jansson studied professional learning of migrant teachers. Focus group discussions and interviews, observation, article reviews and sometimes questionnaires were employed as data generation tools. While my study also adopted focus group discussion and interviews to generate data, I also employed photo-elicitation as opposed to article reviews, questionnaires and observation. These global studies discovered that teachers experienced professional learning through practice, lectures, collaboration, internship, bonding, use of teaching and learning resources and discussions with colleagues. However, the studies did not examine professional learning of mathematics teachers through teaching roles as was the case in the current study.

Within the regional context, the 'Education for All' decade (1980-1990) ushered teacher professional learning opportunities in across Africa as a solution to meeting the urgent demand for quality teachers in schools (Diop 2015). This section reviewed studies on professional learning of mathematics teachers in the regional context. Studies reviewed (Kinyota et al. 2019; Komba and Nkumbi 2016; Mtetwa et al. 2019; Swai and Glanfield 2018) generally, investigated how teachers engaged in professional learning through specific professional learning initiatives rather than individually initiated programmes.

Unlike the reviewed international studies above, Kinyota et al. (2019) in Tanzania conducted a study aimed at establishing how teachers learn from school-based professional learning. This was a qualitative study based on reviews of journal articles. Kinyota et al. (2019) adopted the Chinese school-based professional learning communities as the theoretical framework to help draw lessons for professional learning in Tanzania. Kinyota et al. focused on articles published from 2006-2017 on teacher professional learning and used document analysis for data generation. The study related to my study which also tried to determine how FET mathematics teachers experienced professional learning within the school and also in wider professional sites.

Kinyota et al. (2019) found that teachers engaged in professional learning through practice, observation, reflection and interaction. Teachers planned and delivered lessons while others observed them and thereafter discussed as colleagues the lesson taught (Kinyota et al. 2019). Informed by this finding, this study also sought to understand whether FET mathematics teachers experienced professional learning through lesson delivery and or collegial lesson observation. Professional learning through lesson observation encouraged teacher learning through peer collaboration and feedback (Kinyota et al. 2019; Rahim et al. 2016; Shipper 2019). Patzer (2020) confirms that lesson observation has high quality feedback from impartial and authentic observations. However, Patzer warns that lesson observation can only benefit teachers if it is done for feedback rather than for performance management. Clark and Duggins (2015) consider feedback as a bridge to new learning which has high impact and low cost based on evidence.

Kinyota et al. (2019) recommended that Tanzanian school-based professional learning should formalise professional learning at the school level, allocate specific time for teacher professional learning in schools, offer resources and support for teachers' professional learning and encourage individual teacher initiatives for professional learning. These recommendations are supported by Steyn (2008) who argues that teachers change the way they teach if they take up professional learning opportunities available to them. The study addressed how teachers engaged in professional learning through collegial lesson observation which prompted me to explore how teachers engage in professional learning lesson preparation and delivery.

Whereas Kinyota et al. (2019) in Tanzania studied school-based teacher professional learning, Komba and Nkumbi (2016) also in Tanzania studied teacher professional development in Tanzanian schools. Komba and Nkumbi (2016) aimed at investigating teacher professional learning practices in schools. The study used mixed methods and participants were school head teachers, primary school teachers, ward education coordinators, district education officers, school inspectors and members of the school committees. They used questionnaires, interviews and observation for generating data, contrary to my study which combined interviews with photo-elicitation and focus group discussion. A thematic approach was used for analysing data using frequency tables and percentages; my study adopted open coding as the data analysis tool. However, the thematic approach is usually associated with the qualitative approach rather than the quantitative approach.

Komba and Nkumbi discovered that teachers engaged in professional learning through curriculum change processes and through planned and funded seminars and workshops organised to unpack the new curricular (Komba and Mwakabenga 2019). Based on these findings, the current study sought to discover how FET mathematics teachers realised professional learning through changes in curriculum from 1994 as South Africa went through regular educational transformation. Whereas seminars and workshops were ideal for information dissemination regarding new changes, Corwin (2011) and Hunt (2013) blamed these professional learning spaces for removing teachers from the reality of their classrooms and regarding the teachers as empty vessels into whom information must just be poured without regard for competent teachers as in the deficit model in Kennedy's (2005) study. These arguments prompted a desire to further investigate how FET mathematics teachers engaged in professional learning through workshops and seminars. These planned spaces of professional learning prompted my study to explore how teachers experience learning within school and in wider professional learning sites.

Komba and Nkumbi (2016) also discovered that teachers engaged in professional learning through social networking in promoting transformative learning (Fraser et al. 2007). Manca and Ranieri (2014) in support, added that social networking was a new arena available to teachers to initiate and orchestrate their own professional learning. Liljekvust et al. (2018: 5) also urge that, "The arena for professional development of teachers has changed. … teachers engage in new forms of professional learning made possible by the evolution of the internet." Informed by these ideas, my study further examined how FET mathematics teachers engaged in professional learning through technological resources in their teaching roles.

Unlike Kinyota et al. (2019) and Komba and Nkumbi (2016) in Tanzania, who studied school-based teacher professional learning and learning through curricular change processes respectively, Mtetwa et al. (2019) in Zimbabwe, studied how mathematics teachers participated in continuous professional development. Similar to the current study, the study focussed on the forms of professional learning that mathematics teachers experienced. Mtetwa et al. adopted mixed methods for data generation. Education officials (18), continuing professional development service providers (6) and mathematics teachers in schools (94) were the participants in the study which used interviews and questionnaires for data generation. Based on the number of participants, Mtetwa et al.'s (2019) study was bigger than the current study.

Mtetwa et al. (2019) found that professional learning of mathematics teachers occurred through formally designed workshops, meetings, group discussions, exchange visits and seminars. Mtetwa et al. (2019) like Komba and Nkumbi (2016) concur that professional learning occurred through workshops and seminars. However, Mukeredzi (2015) from a comparative study of Zimbabwean and South African rural school teachers discovered that professional learning through out-of-school workshops and seminars was ineffective as it did not address teachers' classroom needs. Mtetwa et al., however, acknowledged that there were other forms of teacher learning like group discussions and exchange visits between schools. This acknowledgement of the rather limited effectiveness of workshops by Mtetwa et al., also discovered by Mukeredzi, informed my study to further explore how mathematics teachers experienced professional learning through teaching roles. Mtetwa et al. also discovered that the Zimbabwean education system did not recognize informal uncertified professional learning platforms like peer co-learning, e-chat groups and school corridor chats which mathematics teachers experienced. This negated the definition of teacher professional learning through teaching roles adopted in this study which enunciated it as personal engagement in learning situations for individual growth. Swai and Glanfield (2018) in Tanzania who studied mathematics teacher-led professional learning concur with Mtetwa et al. (2019) that mathematics teachers realised professional learning through collaboration and interaction. Mtetwa et al. (2019) like Swai and Glanfield (2018) discovered that teacher-led professional learning was participative and engaging, reflective and experiential, collaborative, practical, contextual and on-going. This discovery confirmed ideas by Villegas-Reimers (2003) where professional learning was a life-long, self-initiated experience that teachers engaged in to cope with reforms in education. Drawing on these ideas my study also sought to investigate how FET mathematics teachers experienced professional learning in school and wider professional learning sites that they found themselves in.

Reviewed regional literature (Kinyota et al. 2019; Komba and Nkumbi 2016; Mtetwa et al. 2019) indicates that teachers engage in professional learning through collegial lesson observation, curricular change processes and exchange visits. These findings indicated that teachers engaged in professional learning in and outside their schools which also influenced this study to investigate how teachers engaged in professional learning within the school and in wider professional sites. Like in this study, regional studies adopted the qualitative approach, except for Komba and Nkumbi (2016) who used mixed methods for data generation. Data were generated through interviews, questionnaires and document reviews. From the studies reviewed teachers experienced both formal and informal professional learning.

On a national level, teacher professional learning in South Africa was triggered by unequal educational opportunities emerging from the apartheid legacy (Ndlovu 2018; Kaino et al. 2015). Mathematics education among black communities lagged behind as the apartheid government had side-lined the subject to protect their labour interests (Ndlovu 2018). This affected the preparation of teachers in teacher education institutions which produced incompetent teachers who lacked confidence in their teaching roles (Steyn 2008). Several studies of teacher professional learning emerged after democracy in 1994 to explore how the learning would mitigate against this anomaly and other related professional educational challenges (Stevens 2005).

Unlike international and regional professional learning studies reviewed above Graven (2002) conducted research on 'Mathematics Teacher Learning, Communities of Practice and the centrality of confidence,' in South Africa. The study examined how mathematics teachers become professional and confident, focussing on their participation in in-service education and training communities of practice. In-service education in this context relates to programmes where mathematics teachers remained teaching in their schools but coordinated to collegially and cooperatively work together within their schools and between schools to engage in life-long learning towards implementing and reviewing curriculum innovations (Graven 2002; Amadi 2013). The fact that Graven's teachers in the in-service programme remained in their jobs relates to the FET mathematics teachers in this study who were professionally learning while on the job, albeit they were not coordinated. Like in my study, Graven's study was framed around an interpretive paradigm and used a qualitative approach. This was a case study where lead educators (subject advisors, Principals and HoDs) in the senior phase participated in the study and data were generated through observation. A social learning theoretical framework was adopted to analyse data. The study relates to my study as it sought to establish how mathematics teachers participated in professional learning through in-service education and training although the two studies focused on different learning phases. In-service training refers to learning in practice similar to learning through teaching roles, which is explored in the current study. Osamwonyi (2016) perceives in-service training as training that is provided to teachers during the course of employment.

Graven (2002) found that mathematics teachers engaged in professional learning through in-service education and training through workshops, individual and group reflections, video recorded classroom observations, written activities through sharing knowledge, and collaborating with and consulting one another as colleagues. The current study sought to understand whether such activities were also experienced by the FET mathematics teachers explored. Other researchers (Meij et al. 2016 in Japan; Vrieling et al. 2018 in Netherlands; Darling-Hammond et al. 2019 in Canada) also indicated that teachers like to share their knowledge, collaborate with others to confirm their knowledge and consult others for advice when they get stuck. Informed by these findings, this study sought to also discover how mathematics teachers experienced professional learning through collaboration.

Graven discovered that teachers engaged in professional learning through different ways that include making meaning (learning through experience), practice (learning by doing), identity (learning as becoming), community (learning as belonging) and confidence (learning as mastery). Contrary to the above, however, teachers in another of Graven's (2004: 8) studies, criticised Department of Education organised workshops "where there was no interaction, only instruction given to us without even understanding what we are required to do on that document (the National Curriculum Statement)". This ineffectiveness of workshops was confirmed by Mukeredzi (2015) and Mtetwa et al. (2019) cited above. However, the forms of learning identified by Graven confirmed arguments by Villegas-Reimers (2003) and Kelly (2006) who assert that professional learning occurs through classroom experiences and practices in the form of reflection on practice. Learning as becoming and learning as belonging informed this study to establish how mathematics teachers engage in professional learning through social gatherings and community involvement in their roles. Graven's (2002) study identified ways of teacher professional learning like practice, experience and others which I also try to establish in my study.

Whereas Graven (2002) in South Africa studied teacher professional learning through in-service training and communities of practice, Chirinda and Barmby (2016), also in South Africa, studied mathematics teacher professional learning through problem-solving. The focus of the study was to determine how mathematics teachers experience professional learning through problem-solving to improve learners' performance. The study used the qualitative approach. My study also sought to explore whether FET mathematics teachers experienced professional learning through critical thinking and problem-solving. Chirinda and Barmby adopted social constructivist theory (Vygotsky 1986) and problem-centred learning as the conceptual framework. The Chirinda and Barmby (2016) study used two qualified and experienced mathematics teachers and their learners as participants and semi-structured reflective interviews to generate data.

Findings from Chirinda and Barmby's (2016) study revealed that mathematics teachers experience professional learning through processes of problem-solving that include understanding the problem, collaborative reflection and encouraging metacognition. Metacognition is understood as a deliberate exercise of monitoring one's own thinking and self-regulation of learning which guides problem-solving. Problem-solving is also viewed as a deep thinking four-way process which includes understanding the problem, strategizing or deciding how to deal with the problem, actioning the plan step by step and reflecting on the path followed to the solution of the problem (Bolden and Thompson 2014). Other researchers (Lassonde et al. 2009; Williams 2010 in Lincoln and De Jong et al. 2019) concur that collaborative learning emanates from brainstorming and collaborative reflection when teachers work together in problem-solving. Like Chirinda and Barmby (2016), Van de Walle et al. (2013) contend that teachers experience professional learning in problem-solving through metacognition. These ideas informed this study to further interrogate processes of critical thinking and problem- solving from which FET mathematics teachers experienced professional learning in their teaching roles.

Whereas Graven (2002) and Chirinda and Barmby (2016) in South Africa studied professional learning in communities of practice and problem-solving respectively, Mhakure (2019), also in South Africa, studied school-based continuing professional learning for mathematics teachers in disadvantaged schools. The study focused on how school-based continuing professional learning could be carried out through lesson study. Mhakure adopted the lesson study as an approach and theoretical framework for analysing data. The lesson study was viewed as a school-centred approach drawing on collaborative experiences of teachers working in the same school mathematics department and focusing on learning of learners. Thus, the study used mathematics teachers in the same school as participants and data were generated through observation and audio and video recording as opposed to my study which did not use any of these instruments.

Professional learning through lesson study where participants experienced professional learning through joint lesson preparation and delivery, however, prompted my study to explore how FET mathematics teachers in this study experienced professional learning through lesson preparation and lesson delivery individually. Concomitant to this, Mhakure (2019) found that mathematics teacher professional learning occurred through lesson planning, delivery, observation, collaboration and reflection from the lesson study. Kinyota et al. (2019) in Tanzania also noted that teachers professionally learn through planning lessons as they identify and design learning activities. In a similar study, Ono and Ferreira (2010) in South Africa also reiterated that teachers learn from observing others while they teach and from reflections made on the lesson as teachers collaborate. Mhakure envisaged that when mathematics teachers plan a lesson, they have to consider different types of learners that they teach and think how they would participate in the lesson. The idea of handling diversity prompted me to establish whether the FET mathematics teachers through their teaching roles also experienced professional learning through handling learner diversity. This is because learner diversity has remained a major challenge in South Africa since the inception of the inclusive education policy where teachers are implored to cater for learners of diverse origins, experiences and learning capabilities (Mahlo 2017; Knight and Wiseman 2005; Winnen 2016).

Local studies (Graven 2002; Chirinda and Barmby 2016; Mhakure 2019) reviewed above, indicate that mathematics teachers in their practice engaged in professional learning through in-service education, training, problem-solving and lesson study in addition to reflection and collegial collaboration. The local studies surveyed adopted qualitative approaches and lesson study. The studies generated data through observation and interviews, as well as audio and video recording. Although the reviewed studies explored professional learning of mathematics teachers, none of them investigated how FET Grade 12 mathematics teachers learn through teaching roles. The next section reviews literature addressing the kinds of professional knowledge teachers gain.

The kinds of knowledge teachers gain through professional learning

Researchers (Mills 2015 in Australia; Ball and Bass 2005 in USA; Ball et al. 2008 in USA) identified difficulties associated with kinds of knowledge mathematics teachers require to teach mathematics effectively in the classroom. This concern led to inquiries emerging globally, to determine kinds of knowledge gained from professional learning which mathematics teachers have to know to teach mathematics competently (Ball and Bass 2005). The exploration was an attempt to inform teacher preparation institutions regarding what aspiring and practising mathematics teachers should know for them to cope in their teaching roles (Wood 2016). This section critically analyses international, regional and national studies on kinds of professional knowledge teachers gain through professional learning to improve instructional practice.

Ball et al. (2005) in Michigan, USA, studied professional learning knowledge mathematics teachers gain to teach mathematics effectively. The study explored the kinds of professional knowledge mathematics teachers gained for teaching. A constructivist paradigm was adopted and similar to my study, a practice-based theory of mathematical knowledge for teaching (MKT) (Ball and Bass 2003) was the theoretical framework for the study. A qualitative approach, where data were generated through intensive job analysis from captured videos of teaching activities, was employed. While Ball et al. (2005) analysed videos of teaching activities for generating data, my study used interviews and focus group discussions complemented by photo-elicitation.

Ball et al. (2005) found that mathematics teachers gained subject matter knowledge and pedagogical content knowledge (PCK) in their teaching roles. The subject matter knowledge gained included common content knowledge, knowledge at mathematical horizon and specialised content knowledge. PCK gained encompasses knowledge of content and students, knowledge of content and teaching, and knowledge of content and curriculum (Ball et al. 2008). Researchers (Kleickman et al. 2013; Schneider and Plasman 2011) reported that PCK was gained, shaped and developed during professional learning through teachers' experiences of and reflection on their teaching practices. The study (Ball et al. 2005) also discovered that teachers gained mathematical knowledge for teaching to identify processes that lead to wrong answers (Hill et al. 2008), and new teaching strategies (Hurrell 2013). Consequently, Ball et al.'s (2008) findings pointed me to some domains of professional knowledge mathematics teachers gain to look out for in my study. Ball et al. recommended that mathematical knowledge for teaching (MKT) be understood as a basis for analysing mathematical teacher knowledge for teaching. However, other studies (Hurrell 2013; Schneider and Plasman 2011) argued that while PCK in MKT was widely used, it lacked clarity of definition and had not been fully explored through research.

Ball et al. (2005) emphasises subject matter knowledge and PCK while downplaying the knowledge of contexts. Grossman (1998) argues that teachers' knowledge in the classroom must be context-specific. In related studies Scheiner (2017) and Celik and Guzel (2017), unlike Ball et al. (2005), add that mathematics teachers also gain knowledge of learners in the form of learners' conceptions and misconceptions about mathematics content through their teaching roles. Complementing Ball et al. (2005), other studies (Carrillo 2013; Jacobsen

2018) indicate that mathematics teachers also gained knowledge of learner diversity and learner background. Ball et al.'s (2005) findings offered my study suggestions for exploring kinds of knowledge that FET mathematics teachers gained through professional learning in their teaching roles in comparison with these findings.

While Ball et al. (2005) in the USA studied kinds of professional knowledge mathematics teachers gained through professional learning, Mills (2015) in Australia, studied professional knowledge gained for teaching mathematics numeracy in the multiplication domain. The focus was on whether professional learning could be linked to the relationship between classroom practice and learner understanding through teacher classroom practices. The study adopted a case study design and mixed methods approach involving four teachers and their learners in two schools. The study generated data through questionnaires, learner assessments, observations and interviews. Observation formed the main instrument for data generation where researchers used field notes, photos and audio and video-recording to capture professional knowledge of teachers in their roles. Mills's (2015) study used the mathematical knowledge for teaching as its theoretical framework. Similarly, in the current study, the mathematical knowledge for teaching formed the theoretical framework for understanding and explaining the kinds of knowledge gained and I drew pointers from Mills's study.

Mills discovered that mathematics teachers gained pedagogical knowledge in the context of content. Pedagogical knowledge in the content context relates to the knowledge teachers gained to facilitate learning of content by learners such as promoting sharing of ideas and discussing problems together (Celik and Guzel 2017). This idea is supported by Sadler (2016) who argues that students' gains in learning cannot be separated from teacher knowledge. This study also sought to determine whether pedagogical knowledge was gained by FET mathematics teachers in their roles. Mills also found that teachers lacked profound understanding of fundamental mathematics. This discovery indicated that teachers lacked content knowledge which would help them to interpret learners' emerging and incomplete thinking (Hurrell 2013; Scheiner 2017; Sadler 2016). In the context of these findings, this study sought to establish content knowledge alongside suggestions made by Ball et al. (2005) in mathematical knowledge for teaching to determine content knowledge gained through teacher roles suitable for classroom practice.

In relation to these findings, Mills (2017: 433) reported that,

> *Lessons appeared to be planned and procedurally implemented and as students struggled with understandings, the teachers lacked the depth and breadth of knowledge required to reframe questions and offer explanations in alternative ways. Seldom were connections made between or within ideas. While the teachers could solve problems themselves, their number sense was weak, and of concern.*

The quotation implies that apart from the lack of content knowledge, the teachers lacked the art of questioning knowledge to guide learners in explaining concepts in alternative ways. McCarthy (2016) considers the art of questioning in mathematics teaching as an important diagnostic tool teachers use to measure learner progress and understanding of concepts during teaching. This is supported by Bryant (2017) who reiterates that the art of questioning helps teachers identify learners struggling with concepts and those coping with their learning. However, Bryant confirms that mathematics teachers have challenges in executing effective questioning strategies. Based on these sentiments, the current study was guided to explore whether FET mathematics teachers also gained the art of questioning knowledge through their teaching roles.

While Ball et al. (2005) in the USA studied professional knowledge mathematics teachers gained to teach mathematics and Mills (2017) in Australia studied professional knowledge gained for teaching mathematical numeracy, Reid and Reid (2017) in Canada studied professional knowledge teachers gained to become competent mathematics teachers. The Canadian study focused on mathematics content knowledge teacher candidates enrolled for a Master of Teaching degree gained to become effective teachers in the classroom, unlike my study which focused on practising teachers in their roles. Reid and Reid used mathematical knowledge for teaching theory with specific reference to content knowledge. The study adopted a mixed methods approach and generated data through pre- and post-test teacher candidates' assessments as well as interviews.

Reid and Reid (2017) made discoveries that through the Master of teaching programme teacher candidates gained mathematical content knowledge and GPK which was important for practicum placements. Reid and Reid established that the mathematical content knowledge and GPK teacher candidates gained were important components of effective teaching, whereas other studies (Ponte and Chapman 2007; Phillip et al. 2008) indicated that strong possession of these forms of knowledge still needed to be complemented by other forms of teacher knowledge to promote effective teaching. Thames and Ball (2010) and Ponte and Chapman (2008) concurred that mathematics teacher educators equipped mathematics trainee teachers with adequate knowledge arguing that when teachers have adequate content knowledge and GPK, they can help their learners optimally. Practicum placements for these teachers were viewed by researchers (Phillip 2007; Thames and Ball 2010) as indispensable. This is because successful mathematics teaching was perceived as dependent on contexts within which learning takes place and that promoted gaining contextual knowledge for these teachers as well. Thames and Ball also found that mathematics teachers gained conceptual mathematics knowledge for effectively explaining concepts and describing connections between them. Ball et al. (2005) with regards to knowledge gained also discovered a lack of coherence between mathematics courses for the Master of Teaching programme and practicum, hence, knowledge gained was not optimal to meet the intended teaching roles. This discovery influenced me to establish whether the professional knowledge gained in this study influenced classroom practice.

From the discussion above, studies in the international context, Ball et al. (2005) in the USA, Mills (2015) in Australia and Reid and Reid (2017) in Canada adopted mixed methods approaches. From the studies, mathematics teachers gained content knowledge and PCK through professional learning to teach mathematics. However, arguments (Hurrell 2013; Schneider and Plasman 2011) show that PCK had not been adequately investigated. Other than the subject matter knowledge and PCK identified in these studies, Mills (2015) indicated that GPK was also gained by mathematics teachers in their teaching roles. Thus, international studies reviewed provided pointers to seek out in this study to establish the kinds of professional knowledge mathematics teachers gain in their teaching roles.

From the regional arena, although African nations advocated for education for all during the 1980 to1990 decade, literacy and numeracy remained a challenge in schools (Akyeampong 2013; Bunyi et al. 2015). This raised concerns leading to inquiries conducted to adequately address the problem among teachers who were generally blamed for lacking knowledge and skills in mathematics and science (Akyeampong 2013). The following section discusses and critically analyses studies across Africa on the kinds of knowledge mathematics teachers gain through professional learning.

Cole (2011) in Ghana studied professional Mathematical knowledge for teaching gained in Ghanaian schools. The study focused on primary school mathematics teachers and the mathematical knowledge for teaching that they gained (Ball et al. 2008) from teacher professional learning programmes to support their instructional practices. This was a qualitative study which used mathematical knowledge for teaching theory as its theoretical framework. Cole adopted a multiple-site case study design involving primary school mathematics teachers as participants. Data were generated through observations and interviews.

Cole (2011) discovered that mathematics teachers in Ghana gained content knowledge and PCK, which constitute mathematical knowledge for teaching (Ball et al. 2008). In addition, Cole found that mathematics teachers also gained knowledge of contexts and knowledge of learner backgrounds, which improved their practices. This was consistent with Grossman (1998) who argued that teachers need to understand particular contexts in which they work and adapt their teaching to those specific school settings. This is consistent with studies (Densmore 2010; Cook and Almack 2019) which emphasise the knowledge of cultural sensitivity among teachers as paramount in handling learners and choosing teaching examples during instruction. Cook and Almack (2019) further suggest that training of teachers should concern itself with events in life, changing communities and current social problems. This was consistent with arguments raised earlier by Carrillo (2013) and Jacobsen (2018) that effective teachers should utilise knowledge of learner diversity and background during instruction. Informed by these findings and arguments, this study sought to determine other kinds of knowledge mathematics teachers gained and any particular sensitivities that the teachers developed through teaching roles in the South African context. However, the study by Cole (2011) further established that mathematical knowledge for teaching gained was positively associated with the mathematical quality of instruction.

While Cole (2011) in Ghana studied the mathematical knowledge for teaching gained through teaching roles in Ghanaian schools, Wanjala et al. (2015) in Kenya studied pedagogical knowledge gained by integrating computers in mathematical teaching. The study focused on secondary school mathematics teachers examining the pedagogical knowledge gained in integrating computers with mathematics teaching. Unlike my study's qualitative approach, Wanjala et al. adopted both a mixed methods approach and a descriptive survey design. The technology acceptance model was used as the theoretical framework, as opposed to my study which adopted mathematical knowledge for teaching theory. Wanjala et al. involved 250 secondary school mathematics teachers as sources of data, generated through questionnaires, interviews and observations.

Wanjala et al. (2015) found that using computers in mathematics teaching helped teachers to gain GPK and skills. Through computer application, teachers realised perceived usefulness, perceived ease of use, technical support and pedagogical routine practices. The perceived usefulness was knowledge gained, related to mathematics teachers conceiving the integration of computers in mathematics teaching as technology increasing their performance in practice (Hart and Laher 2015). Perceived ease of use meant that knowledge of technology gained was viewed as reducing teachers' physical effort while maximizing outcomes during instruction (Matlala and Kheswa 2019). Researchers (Hart and Laher 2015; Isiyaku et al. 2018) also reiterate that technological knowledge of computers enhances technical support and innovation in teaching strategies which are aligned to changing times through technological transformation. Dollarhide (2019) argues that computer-based technology is vital for facilitating the sharing and gaining of ideas, thoughts and information through networking and the establishment of communities of practice. It was vital in this study to determine the kind of professional knowledge that the FET mathematics teachers studied gained through the use of technological resources in their teaching roles.

Anney and Bulayi (2020) in Tanzania studied mathematics teachers' pedagogical content knowledge gained in learner-centred approaches, as opposed to Cole (2011) in Ghana and Wanjala et al. (2015) in Kenya who studied MKT and pedagogical technological knowledge mathematics teachers gained respectively. The study took a qualitative approach and adopted a multiple case study design. Four mathematics teachers from secondary schools were identified as participants. The study used Magnusson's components of the teachers' PCK as a lens to examine mathematics teachers' PCK gained in learner-centred approaches. Data were generated through classroom observations, interviews, teacher self-reflections and document reviews.

While my study sought to determine all the kinds of knowledge FET mathematics teachers gained through professional learning broadly in their teaching roles, Anney and Bulayi (2020) specifically focused on PCK gained in learner-centred approaches. Anney and Bulayi (2020) confirmed that mathematics teachers gained PCK related to learner-centred instructional strategies. The study also found that mathematics teachers who gained strong PCK were able to apply learner-centred approaches by combining content knowledge with knowledge of students, knowledge of teaching and knowledge of the curriculum. This confirmed arguments by Hill et al. (2008) who explained that PCK blends the knowledges of students, teaching and the curriculum. These findings are consistent with Shulman (1987), Grossman (1998) and

Cogill (2008) who conceived PCK as knowledge needed in the process of teaching. Drawing on the study by Anney and Bulayi, the current study examined whether and what forms of PCK mathematics teachers gained through use of different teaching strategies, in particular learner-centred pedagogies (Fletcher et al. 2018).

Unlike Cole (2011) in Ghana, who studied mathematical knowledge for teaching, Wanjala et al. (2015) in Kenya, who focused on pedagogical knowledge and Anney and Bulayi (2020) in Tanzania, who examined PCK acquired by teachers in learner-centred approaches, Mungure (2017), also in Tanzania, studied teacher knowledge gained through teaching approaches adopted in preparing science and mathematics teachers during training. Mungure focused on teachers in training; my study investigated qualified teachers in the field. Examining how science and mathematics teachers are trained, Mungure analysed the kinds of knowledge these student teachers gained in preparation for teaching practice. The study adopted a case study design and qualitative approach. Participants were trainee teachers at one teachers' college. Mungure generated data through interviews and focus group discussions and employed content analysis to unpack the data, contrary to my study which used open coding.

Mungure (2017) discovered that science and mathematics teachers gained content knowledge, GPK and PCK. However, training did not adopt teaching strategies that promoted gaining science process skills of problem-solving and critical inquiry. The study found that lecture method, as well as question and answer, were the most popular strategies employed. Mungure's findings indicated that content, pedagogy and PCK that were gained were insufficient for classroom practice but knowledge of science process skills was vital. This confirmed studies by Kirimi and Njagi (2016), who discovered that the integration of science process skills in the teaching of mathematics improved teachers' delivery. This argument was confirmed by Gultepe (2016), who considers the knowledge of science process skills as critical in developing teacher skills of observing, predicting, experimenting, and inferencing necessary for mathematics teachers in their teaching roles. Thus, Kirimi and Njagi (2016) recommended that Teacher Training Colleges and Universities should include learning of science process skills in instructional methods and materials. From these works, this study sought to examine whether FET mathematics would make references to gaining such kinds of professional knowledge through teaching roles.

Regional studies reviewed above (Cole 2011; Wanjala et al. 2015; Anney and Bulayi 2020; Mungure 2017) showed that mathematics teachers gained content knowledge, PCK, GPK and skills in the use of technologies. However, the study by Mungure (2017) indicated that mathematics teachers need other forms of professional knowledge. Similar to my study, these were qualitative studies that generated data through interviews and focus group discussions although some employed observation, self-reflections and document reviews. However, none of the studies explored kinds of professional knowledge that FET mathematics teachers gained through teaching roles.

Studies (Pournara et al. 2015; Bertram 2011; Spaull et al. 2007) in South Africa indicated that mathematics learners performed poorly in international assessments such as TIMSS, PISA, SACMEQ, World Bank and others. Further inquiry into this phenomenon (Pournara et al. 2015; Taylor and Taylor 2013; Bansilal et al. 2014) discovered that mathematics teachers operated well below the subject matter knowledge that they had to teach. This study sought to explore how the mathematics teachers learnt and what professional knowledge they gained from professional learning which would possibly enhance their teaching practice. The subsequent section reviews and analyses studies conducted nationally on kinds of knowledge mathematics teachers gain through professional learning.

Like Cole (2011) in the regional context in Ghana, Labuschagne (2016) in South Africa studied mathematical knowledge that mathematics teachers gained for secondary school teaching. The study focused on mathematicians from the South African mathematical society and explored their perspectives on what knowledge mathematics teachers in secondary schools gained through professional learning for effective teaching. The study adopted a qualitative approach and generated data through interviews, observation and questionnaire surveys. The mathematical knowledge for teaching (MKT) (Ball et al. 2008) and the Activity theory (Vygotsky 1978) were used as frameworks for data generation and analysis.

Labuschagne (2016) found that mathematics teachers gained technological knowledge, content knowledge and GPK for teaching. Labuschagne, like Wanjala et al. (2015) in Kenya, indicated that technological knowledge is vital in mathematics teaching to complement content and GPK. Aligned to the Activity theory, Labuschagne discovered that mathematics teachers gained knowledge for teaching in the form of the tools (theories of teaching), the subject (content knowledge), the rules (culture of mathematics teaching), the community (stakeholders in mathematics teaching), division of labour (collaboration-teaching as relational), the object (teacher development adjusting teaching methods and practices) and the outcome (understanding mathematics teaching). Labuschagne realised that the mathematics teachers still lacked the tools and the subject knowledge to make a significant difference in their roles. This confirmed studies by Venkat and Spaull (2007) in South Africa who also discovered that mathematics teachers lacked content knowledge. Labuschagne's kinds of teacher professional knowledge suggested to me kinds of professional knowledge to look out for in this study in investigating what FET mathematics teachers learnt through teaching roles. While Labuschagne (2016) in South Africa studied the knowledge that mathematics teachers gained for teaching in secondary schools, Cereseto (2016), also in South Africa, studied what and how teachers learn in professional learning communities. The study aimed at investigating the knowledge teachers gain in subject based professional learning communities. My study, unlike Cereseto's (2016), focused on professional knowledge gained through teaching roles. Unlike Labuschagne, who focused on knowledge teachers gained for teaching mathematics, Cereseto examined knowledge teachers gained for teaching regardless of the subject. Cereseto's study was a qualitative case study which used a framework of knowledge for teaching (Shulman 1987; Ball et al. 2008; Winch 2010) for generating and analysing data and explaining findings. Data were generated from minutes of meetings, audio-recordings, interviews, questionnaires and learning reflections from journals.

Cereseto discovered that teachers learnt more practical knowledge than subject matter knowledge in professional learning initiatives. The study also found that teachers with more subject matter knowledge contributed more practical knowledge during meetings than those with weaker subject matter knowledge. While practical knowledge is understood as procedural 'how-to' perform knowledge (Rittel-Johnson et al. 2016; Star and Gabriel 2013), generally viewed as the GPK, in the teaching of mathematics practical knowledge relates to the knowledge of learners' everyday experiences used in teaching activities (Haara 2015; Ponte 2017) which enhances learners understanding of mathematical concepts. Thus, in this context, this is the knowledge which promotes retention and the creation of meaning of mathematical ideas and facts by learners during instruction (Grossman 1990). Mulholland (2014) considers the use of practical knowledge in mathematics teaching as the elasticity of teacher manipulation of the environment. Thus, my study sought to investigate both the GPK-related and the mathematics-related practical knowledge that FET mathematics teachers gained through professional learning which influenced their practices.

Labuschagne (2016) and Cereseto (2016) in South Africa studied knowledge that mathematics teachers gained in the mathematics classroom, Mukeredzi (2013), also in South Africa, studied professional knowledge gained through teacher roles. The study focused on professional learning of unqualified teachers in rural South Africa and Zimbabwe analysing what these teachers learnt and how they developed professionally through their roles. The study relates to my study as they both examine professional knowledge gained through teacher roles. Mukeredzi's study adopted a qualitative approach and generated data through interviews and photo-elicitation, similar to the current study. The conceptual frameworks revolved around teacher knowledge and professional development while the current study adopted the mathematical knowledge for teaching theory and the triple lens theory.

The research found that professionally unqualified practising teachers gained general pedagogical knowledge, pedagogical content knowledge and knowledge of context through their teacher roles. The current study which sought to determine the kinds of professional knowledge teachers gained through teaching roles established similarities and differences with those revealed by Mukeredzi (2013). However, Mukeredzi's study differs from my study in that her participants were professionally unqualified teachers in Zimbabwe and South Africa while my study explored professionally qualified FET teachers in the Eastern Cape province in South Africa. While Mukeredzi (2013) studied professionally unqualified secondary school teachers regardless of the subjects they taught, my study explored professional learning of qualified teachers who taught FET mathematics. This was a significant difference in that different subjects demand different approaches and strategies for teaching, hence, different professional knowledges (Gill 2020). This is confirmed by Zdonek (2016:1) who expresses that, "professional development could be effective if we differentiate it by gauging teachers ... utilizing their interests and involving them in the process." Thus, professional learning knowledge for teachers would be better explored among teachers who teach the same subject, hence, the focus of this study on FET Grade 12 mathematics teachers.

National studies reviewed above indicated that teachers gained content knowledge, PCK, GPK (Labuschagne 2016; Mukeredzi 2013), technological knowledge and practical knowledge (Cereseto 2016) and knowledge of contexts (Mukeredzi 2013). In one study (Mukeredzi 2013) data were generated through interviews and photo-elicitation like in my study. Other studies used observations and reflection to complement other data sources, unlike in my study. While these studies focused on perceptions of teachers in their roles to understand the kinds of knowledge gained (Mukeredzi 2013; Cereseto 2016), Labuschagne (2017) focused on perceptions of mathematicians to determine the kinds of knowledge for teaching that they gained. Teacher knowledge was gained through professional learning communities and through teacher practice. This is distinct from this study which explored professional knowledge of FET mathematics teachers that they gained through teaching roles. The following section discusses literature on the ways in which professional learning influences mathematics teachers' pedagogical practices.

How professional learning influences teacher pedagogical practices.

Teachers must be "active agents" of their professional growth (Schleicher 2012: 73). Professional learning is considered a critical factor for developing and improving teacher and professional quality (Colbert et al. 2008; Geringer 2003). This assertion is founded on the notion that teacher quality is dependent on the forms of professional learning individual teachers engage in which in turn impacts their classroom practices (Peckover et al. 2006). This was reflected by one of the participants in Reid and Reid's study who said, "There was a difference between being very good at Mathematics and being able to teach it" (Reid and Reid 2017: 3). The quotation implies that professional learning goes beyond teachers knowing the subject matter to actually influence how they teach it. The subsequent section reviews international, regional and national academic work on professional learning influence on teachers' pedagogical practices.

Gee and Whaley (2016) in the USA studied practice-centered professional learning to enhance mathematics teaching. The study focused on how professional learning through lesson study increased teachers understanding of mathematics content and effective mathematics pedagogy. This was a case study of elementary mathematics teachers enrolled in a two-year professional development programme. The study generated data through interviews, teacher journal reflections and video recording, unlike my study which employed face-to-face interviews, focus group discussion and photo-elicitation.

Gee and Whaley (2016) discovered that mathematics teachers collaborated during professional learning and consequently influenced their questioning strategies, student discourse and thinking. Gee and Whaley found that participation in a professional learning programme concomitantly changed teachers' practices. One of their participants in this regard reported that, "I love reflecting with a group … They notice things that I didn't see. … as we got into this, we could see a different way of teaching, you know. It was really good, it made me better myself" (Gee and Whaley 2016:95). Reflecting as a group is a process where teachers together look back at their actions to identify what they have done, locate the purpose of their actions, question their actions and develop alternative actions which are more effective for their roles (Shandomo 2010). Reflecting as a group is shown in the quotation above as a powerful aspect of professional learning which influences teachers' perceptions and approaches to their roles. This is confirmed by Marvel (2018) who perceives reflecting with a group as crucial in professional learning, giving new teachers and veterans alike a means to deeply understand new classroom practices. Drawing on these assertions, this study also sought to determine how collaboration and collaborative reflection influenced FET mathematics teachers' classroom practice in their teaching roles.

Unlike Gee and Whaley (2016) in the USA, Colbert et al. (2008), also in the USA, studied the impact of teacher-driven professional learning on pedagogy and student learning. The study focused on mathematics and science teachers examining teacher content knowledge, pedagogical practices and learners' learning during instructional practice. The study relates to the current study as both studies focused on the influence of self-initiated professional learning, albeit my study includes externally initiated learning. While Colbert et al. (2008) explored the extent to which professional learning had influenced teachers in their roles, this study sought to determine the influence of professional learning on mathematics teachers' pedagogical practices. The study used a phenomenological design which incorporated both quantitative and qualitative approaches, as the aim was to understand the lived experiences of teachers who took part in a professional learning programme. Data were generated through in-depth interviews, audio-recordings, surveys and learner progress reports collected from teachers partaking in the professional learning programmes.

Colbert et al. (2012) and Garner et al. (2018) indicated that teachers gained self-confidence, self-efficacy, empowerment and professionalism from their professional learning which influenced their self-perceptions of how well they could perform as educators, which raised their self-esteem. These findings influenced me to determine whether professional learning influenced teacher confidence, effectiveness and perceptions of FET mathematics teachers through teaching roles in this study. Confirming professional learning influence on teachers' self-esteem, Heggart (2016) and Wineburg (2015) in the USA explained that self-esteem instils confidence in mathematics teachers which motivates them towards instructional quality. Colbert et al. found that through professional learning mathematics teachers became more proactive and willing to improve their own learning and teaching experience. They also found that mathematics teachers improved their knowledge of teaching theories, pedagogies and instructional strategies through professional learning. In similar studies Jacobsen (2013) and Hurrell (2013), both in Australia, concurred, adding that connections between theories, pedagogies and strategies influenced teachers' coherence in teaching. Colbert et al. also discovered that professional learning helped teachers to influence learners' thinking processes and the pedagogical knowledge gained improved their subject integration and developed their skills in teaching resource utilisation. Informed by these findings, this study explored how professional learning influenced FET mathematics teachers' competence and effectiveness in relation to aspects highlighted by Colbert et al. Other studies (LINQ 2018; Shah 2018; Blandford 2003) also perceived forms of knowledge, materials and equipment as tools of the trade for which mathematics teachers were influenced to account. While Colbert et al. (2011) discovered these influences of professional learning from a professional learning programme, my study sought to explore how professional learning influenced FET mathematics teachers' maintenance of resources allocated to them for teaching such as calculators, text books and other teaching and learning materials.

Colbert et al. (2011) in the USA studied the impact of teacher-driven professional learning; in Norway, Postholm (2018) studied how teacher professional learning influenced teacher practice in schools. The study, unlike Colbert et al.'s, aimed at reviewing the most recent studies focusing on teachers' professional learning in schools and analysed findings with regards to how this influenced the teachers' practices. A qualitative approach was employed and data were generated from identified articles across the world. Related to my study, data were also analysed through open coding and categorising according to established themes. Cultural historical activity theory (CHAT), (Vygotsky 1978; Mentz 2017) was adopted for data generation, analysis and explaining findings. Postholm's study reviewed studies conducted in 2016 and 2017. This study depended on primary sources, the FET mathematics teachers, in their contexts.

Postholm (2018) found that teachers experienced self-improvement from professional training and development opportunities provided by their leaders and through collective inquiry. Consistent with this, Pang et al. (2016) perceived school principals as better placed for establishing productive learning environments for their teachers and, hence, influencing their practices. Other studies (Adolfsson and Alvunger 2017) in Sweden, also valued professional learning initiated by school leadership as effective in influencing teachers to develop common goals, increase their knowledge of the curriculum and participate in professional discussions which influenced the teachers' practices. However, Salleh (2016) in Singapore discovered that leadership failed to promote a collective purpose and common goals among teachers during professional learning activities. This compromised the special attributes of teacher learning such as team building, collegiality, bonding and trust (Salleh

2016) which have the capacity to sustain teacher learning for longer periods and influence learner achievements. From these findings related to school-initiated professional learning the current study also examined the influence of both Department of Education and school-based initiatives on FET mathematics teachers' pedagogical practices.

Postholm discovered that professional learning influenced teachers' identification of their teaching gaps for improvement. Cravens and Wang (2017) in China argued that expert teachers as leaders served as role models for teachers' professional growth. Postholm also discovered that partnerships during professional learning influenced teachers' reflections on their practices, which influenced them to engage with their own teaching. The findings further indicated that professional learning improved teachers action research skills and alternative assessment strategies in their classroom pedagogical practices. The kinds of FET mathematics teacher pedagogical skills, strategies and attributes that were impacted by their professional learning had also to be established in this study. Postholm further established that teacher reflections on their practice improved their confidence. Cravens and Wang (2017), in support, explained that professional learning developed teacher confidence and their ability to express themselves adequately in front of their learners. Informed by these ideas my study also sought to determine whether professional learning influenced FET mathematics teachers' pedagogical practices around classroom communication.

Colbert et al. (2011) in the USA and Postholm (2018) in Norway studied teacher-driven professional learning and influence of professional learning in schools respectively. On the contrary, Payne (2018) in the USA studied professional learning and its influence on teacher practice and student achievement. The study focused on teachers and students in primary and high schools and investigated the characteristics of effective professional learning and how it influences changes in teacher practice. The study by Payne was closely aligned to my study and I drew guidance on procedures to explore the influence of professional learning on FET mathematics teachers' pedagogical practice. Payne (2018) used a mixed methods approach where surveys, interviews and student benchmark assessments were used for data generation. The study adopted Lippitt's (1987) managing complex change model and Guskey's (1985) model of teacher change as frameworks guiding the study, whereas my study employed the mathematical knowledge for teaching theory and the triple lens theory in combination.

Payne (2018) discovered that professional learning through past experiences influenced teachers' beliefs and practices. My study tried to determine whether the FET mathematics teachers' dispositions, attitudes and beliefs were influenced by their professional learning. Learning through past experiences relates to learning from reflection on those experiences where they determine what they could have done differently to improve. Glaze (2001), supported by Victor (2018), confirms this learning as learning from reflection on experiences. Mukeredzi (2015) concluded that learning emanates from reflection on experiences and not from experiences on their own. Victor (2018) argues that when teachers explore their experiences, they tend to understand the contexts in which they work, transform their perspectives and deepen understanding of their roles. In this regard, professional learning challenges teachers to rethink their teaching practices, while supporting them to understand and accommodate new ideas, as well as synchronise them with their experiences of practice (South West Educational Development Laboratory 2002).

Payne's (2018) study found that professional learning influenced coherence throughout an education system which in turn influenced expectations for teachers in their roles. Hammerness (2006) conceives coherence as shared understandings in the organisation in a manner in which opportunities to learn have been arranged to achieve the intended goals of teaching. Coherence provides direction, systematic relations and intelligible meaning which transmits a sense of purpose, order, intellectual, as well as practical, control. Thus, properly planned and organised professional learning programmes provide coherence within instructional practices (Lindvall and Ryve 2019) and this influences teacher understanding of their processes of instruction. Payne (2018) established that individualised professional learning leads to real change in practice. Individualised professional learning always depicts individual teacher values and goals (Barni et al. 2018) which primarily influences their behaviour and that of their learners. While the study (Payne 2018) examined professional learning's influence on teacher practice and student achievement in primary and high schools, my study was limited to professional learning's influence on FET mathematics teachers' pedagogical practices without the aspect of students' achievement.

The international literature reviewed (Gee and Whaley 2016; Colbert et al. 2011; Postholm 2018; Payne 2018) shows that professional learning influences teachers' personal attributes such as their confidence and self-esteem and increases their knowledge of the job, which enhances classroom practice. From the studies above, professional learning also influenced teachers' behaviour, attitudes and beliefs in their practice, which enhanced their professionalism in their roles. The studies used mixed methods (Colbert et al. 2001; Payne 2018), while my study, like Postholm's (2018), adopted a qualitative approach. The following section reviews regional literature on how professional learning influences teacher pedagogical practices.

While teacher preparation institutions may equip teachers with knowledge and skills for effectiveness in their roles, their influence may not be adequate without on-going professional learning. Unprecedented challenges (Abdulrazak 2020) emerging from technological development and national reforms require professional learning to provide on-the-job solutions to teachers' practices. Akomolafe et al. (2013) and Musset (2010) conceive of professional learning programmes as necessary for influencing teachers' competencies, especially in constantly changing school environments, to increase their proficiency. Thus, for Africa, the rationale for running teacher professional learning programmes was to upgrade and equip teachers with knowledge and skills consistent with influencing and improving classroom practices (Timperley 2015), given the advent of national reforms after the 'Education for all' policy of 1980-1990.

Abdulrazak (2020) in Ghana studied the perspectives of teachers on the influence of professional learning on their teaching through an exploration of primary and high school teachers. This was a qualitative case study which used constructivist theory (Piaget 1973; Vygotsky 1978) as a lens for data generation, analysis and presentation as opposed to the mathematical knowledge for teaching and the triple lens theories used in this study. Data generation employed document analysis and semi-structured interviews whereas my study employed face-to-face interviews, focus group discussions and photo-elicitation. My study targeted only FET Grade 12 mathematics teachers whereas Abdulrazak explored both primary and high school teachers. However, the studies were related as they both adopted a qualitative approach.

Abdulrazak (2020) found that professional learning was necessary for continuous teacher upgrading to address rising classroom challenges. The study further discovered that teachers were able to sustain the changes made to their teaching practice through their professional learning. These findings confirmed arguments raised by Mizell (2010) that professional learning transformed teachers as they learnt better ways of teaching, developed better organisation and planning skills, gained new knowledge and skills and continued with their education. Acknowledging the influence of professional development on teacher practice, Mizell (2010: 18) argues that, "Good teaching is not an accident. … all effective teaching is the result of study, reflection, practice and hard work. Students … learn more if their teachers regularly engage in high quality professional development." These perceptions about the influence of professional learning informed me to investigate whether FET mathematics teacher professional learning through teaching roles influenced their pedagogical practices in similar ways.

Whereas Abdulrazak (2020) in Ghana studied the influence of professional development on teachers' classroom practice, Coffie (2019), also in Ghana, studied the influence of continuous professional development on the teaching of Physics in Colleges of Education. The study focused on Physics tutors assessing the perceived influence of their continuous professional learning programme on the teaching of Physics at Colleges of Education. Unlike my study, this was a quantitative case study which adopted a descriptive survey method for data analysis and presentation. The study hypothesized that there was no statistically significant difference in the perceived influence of professional development by the Physics teachers based on their experience. Statistical methods were adopted for data analysis, whereas I adopted qualitative methods to analyze my data.

Coffie (2019) established that professional learning had a great influence on the teaching practices of teachers in Physics. The study also discovered that teacher training programmes had influenced teachers' interaction with their learners and promoted learner-centred approaches, as well as gender responsiveness. In a similar study, Collen (2013) in Namibia found that teacher-learner interaction influenced both teachers' and learners' performances, understanding, as well as the environment that prevailed during instruction. Learner-centred approaches have been highlighted as current reforms necessary for improving mathematics outcomes during instruction (Vale and Weaven 2010 in Australia). These findings were supported by Buabeng (2015) in New Zealand, who reported that initial teacher qualifications would not prepare teachers adequately in all areas of the curriculum: as such in-field professional learning would contribute to filling that gap. One wonders whether these influences on approaches to teaching Physics would also apply in the pedagogical practices of FET mathematics teachers, hence the need to explore.

Malundu (2018) in Uganda studied teacher professional development and its influence on the quality of pedagogical practices, a diversion from Abdulrazak (2020) in Ghana and Coffie (2019) also in Ghana, who studied teachers' perceptions of the influence of professional learning on teacher practices and on the teaching of Physics respectively. Malundu focused on secondary teachers and education officials, aiming at analysing the influence of teacher professional development on the quality of pedagogical practices in public schools. Unlike in my study where qualitative approaches were adopted, both quantitative and qualitative approaches were employed in Malundu's study. Data generation was done through surveys, interviews, observation and documentary analysis contrary to interviews, focus group discussions and photo-elicitation adopted in the current study.

Malundu (2018) discovered that professional learning influenced the quality of lesson preparation, teaching methods and learner assessment of learners. The study found that teachers' pedagogical practices were positively influenced by the quality of professional learning the teachers engaged in. The influence of professional learning on teachers' pedagogical practices was elaborated by Wallhead (2006) who noted that it was responsible for extending and deepening teachers' teaching practices and subject matter. Antony and Walshaw (2009) and Umugiraneza et al. (2017) reiterated that professional learning optimizes opportunities for mathematics teacher learning, continually updating their content, teaching methods and assessments strategies. The findings by Malundu (2018) provided a yard-stick through which my study could examine and analyse the influence of FET mathematics teachers' professional learning on their pedagogical practice.

The reviewed regional studies (Abdulrazak (2020; Coffie 2019; Malundu 2018) indicate that the influence of professional learning related to upgrading and equipping teachers with new knowledge and skills in their pedagogical practice. Teachers gained knowledge related to teaching strategies, learner-centred approaches, improved teacher-learner interaction, quality lesson presentation, teaching methods and learner assessments. The studies indicated that professional learning upgraded teachers through continuing teacher professional learning. The studies generally employed interviews, observation, surveys and document analysis as methods of data generation. However, unlike my study, they used both quantitative and qualitative methods of analysing data, whereas my study adopted only qualitative data analysis approaches.

Professional learning influence on teachers' pedagogical practices in South Africa has been marred by ineffective professional learning programmes, lack of coordination and the absence of proper implementation policies (Mestry et al. 2009; Tsotetsi 2013; Chiponga and Mutodi 2019). Notwithstanding the benefit of professional learning in post-apartheid South Africa, teacher learning programmes do not influence teacher pedagogical practices, learner performance and achievements, as the education system continues to experience poor learner achievements in national and international assessments which are blamed on teacher incompetence (Steyn 2008; Pournara et al. 2015; Venkat and Spaull 2007). This following section reviews national studies on the influence of professional learning on mathematics teachers' pedagogical practices.

Hadebe-Ndlovu (2016) in South Africa studied teachers understanding of pedagogical practices in the teaching of mathematics at Grade One level. The aim was to understand pedagogical choices available to mathematics teachers and how such choices influence learner learning and teacher practices. The study examined teachers' understanding of pedagogical learning theories applicable in teaching mathematics. This was a qualitative case study which generated data through semi-structured interviews, classroom observations and document analysis unlike my study. Hadebe-Ndlovu drew from constructivism and Bernstein's pedagogic device theories for data analysis.

Hadebe-Ndlovu (2016) discovered that professional learning influenced mathematics teacher knowledge of pedagogic theories and content. From this study, professional learning influenced teachers to maintain the required level of knowledge and understanding of their practice, drawing on pedagogic theories. Seah (2018) indicated that pedagogic theories such as valuing prior learning, setting appropriate levels of challenge and linking learner attainment to cultural values rather than to specific mathematics teaching, were critical in influencing teachers' teaching practices. Thus, values/valuing play a major role in influencing the pedagogy of mathematics teaching. Seah and Andersson (2015:169) argued that:

> *Values/valuing provides the individual with the will and determination to maintain any course of action chosen in the teaching of mathematics. They regulate the ways in which teachers' cognitive skills and emotional dispositions are aligned to teaching in any educational context.*

From this quotation, it is evident that values/valuing play an important role in the teaching of mathematics where individual teachers value/valuing mathematics will define how they view their roles in their practice. Hence, this study sought to determine whether values played any role in influencing FET mathematics teacher pedagogical practices.

While Hadebe-Ndlovu (2016) in South Africa studied pedagogic theories in teaching mathematics, Chigonga and Mutodi (2019) studied the cascade model of mathematics teachers' professional development and how it influences teacher practices in public schools. Similar to my study, this was a qualitative study which generated data through focus group discussions, albeit my study included individual interviews and photo-elicitation.

However, Chigonga and Mutodi (2019) found that teachers disapproved of professional learning through cascading, blaming the approach for not being connected to their classroom practices. They recommended that teacher professional learning programmes should promote ideas, knowledge and skills that improved classroom settings and influenced teacher concerns in their practice. While the teachers condemned cascaded workshops, scholars (Guskey 2009; Sayed 2016; Bell and Gilbert 2005) perceived workshops of any form as important for building connections and interactions among colleagues, facilitating content gap filling and sharing strategies for teaching particular topics. Like in Kennedy's (2005) study the cascade model has been adopted and valued for its cost effectiveness and ability to broadcast knowledge and skills to many teachers in a short space of time. While the cascade model has been viewed as a catalyst for rapid change through its layers of information dissemination, Bett (2016) argues that the cascade model is associated with challenges of diluting content through information transfer from one group to the next. Similar to Chiponga and Mutodi (2019), Bett further condemns it for not influencing teacher practice, as focus is on knowledge and skills dissemination disregarding teacher attitudinal and value change. These contradicting views prompted me to explore how professional learning through teaching roles influenced FET mathematics teachers in one South African district.

Unlike Hadebe-Ndlovu's (2016) and Chiponga and Mutodi's (2019) studies in South Africa discussed above, Tsotetsi (2013), also in South Africa, studied 'The Implementation of Professional Teacher Development Policies: A continuing Education Perspective.' The study aimed at designing a strategy to effectively implement CPD programmes that would influence teacher practices in schools. Data were generated from school management, integrated quality management coordinators, subject advisors, school management teams, teachers, teacher unions and school governing board members, whereas this study used FET Grade 12 mathematics teachers only as sources of data. Tsotetsi adopted critical emancipatory research and total quality management as a theoretical framework and critical discourse analysis for analysing the data, as opposed to the qualitative approach adopted in the current study.

Contrary to the above discussion of influences on professional learning, Tsotetsi (2013) found that professional learning did not influence teachers in their pedagogical practices. Tsotetsi made the following discoveries: that practising teachers were not involved in the design of professional learning programmes, professional learning programmes were not relevant, teacher learning plans were not coordinated, leaders were ineffective and programmes were not compliant with school contexts which consequently compromised professional learning influence on teachers' practices. These discoveries were a result of professional learning organised by instructional leaders such as school principals, subject planners and advisors. This was opposing arguments raised through research (Postholm 2018; Hauge and Wan 2019) that professional learning was essential for influencing teacher professionalism, changing classroom practices and generating strategies for instructional practices. However, Mulford (2003) argues that teacher leaders are essential in influencing teacher practice through planning and organising professional learning programmes for their teachers. Thus, the discoveries by Tsotetsi (2013) became vital in this study to establish whether such issues played up in the professional learning of FET mathematics teachers and how they influenced their instructional practices.

National studies (Hadebe-Ndlovu 2016; Chiponga and Mutodi 2019), unlike Tsotetsi (2013), indicated that professional learning influenced teachers' knowledge and understanding of their practices to attach value to their performance and generate new teaching strategies. Tsotetsi (2013) showed that leader-organised professional learning lacked classroom relevance and, as a result, did not influence teacher pedagogical practices. Informed by Tsotetsi's study, my study also explored whether and how professional learning of FET mathematics teachers through workshops organized by instructional leaders influenced their teaching practice.

Having reviewed literature related to how teachers engage in professional learning through their roles, the kinds of professional knowledge they gain and whether the learning influences their pedagogical practices, I move on to discuss the theoretical framework that guided my study. The next section, therefore, discusses the theoretical frameworks.

THEORETICAL FRAMEWORK

Any research requires a structure and a guide to provide parameters and direction in order to achieve its focus and purpose. This was paramount in this study of FET Grade 12 mathematics teachers' professional learning through teaching roles and its influence on pedagogical practices, to ensure that there was flow throughout the processes of data generation analysis and explaining findings.

This study used the triple lens theory (Reid's quadrants, Bell and Gilbert's three aspects of professional learning and Kennedy's Models of CPD: A Framework for analysis in Fraser et al. 2007). This was complemented by the mathematical knowledge for teaching (MKT) theory (Ball et al. 2008) to address the different research questions. The triple lens theory was a structural lens guiding the process of data generation and analysis answering subsidiary Question One which sought to discover how FET Grade 12 mathematics teachers engage in professional learning through teaching roles. However, this theory would not be applied to explore the kinds of knowledge that the teachers gained from their learning and how the learning influenced these teachers' pedagogical practices, hence, the mathematical knowledge for teaching theory was included.

The chapter will discuss the two theoretical frameworks, covering historical development, principles and application in this study. Some of their weaknesses and how they were addressed in the study to minimize their impact on the findings are also discussed.

Eisenhart (1991:205) views a theoretical framework as, "a structure that guides research by relying on formal theory … constructed by using an established, coherent explanation of certain phenomena and relationships." This definition is supported by Grant and Osanloo (2014:13) who conceive the theoretical framework as, "a blueprint for the entire dissertation inquiry … the guide on which to build and support your study … the structure to define how you will philosophically, epistemologically, methodologically and analytically approach the dissertation as a whole." In the context of these definitions, I understand the theoretical framework as nothing less than the basis upon which a study is founded, maintained and established.

The triple lens theory

The increasing demand for teacher professional learning world-wide gave rise to changes in the professional and political context in Scotland (Fraser et al. 2007). Major among these changes was the analysis and evaluation of continuing professional learning policies, practices and impact. The triple lens theory was developed to understand and explain these complexities (Kennedy 2005). The theoretical framework originated from a background where the theories that constitute it were inadequate to encompass all the complex factors that were involved in teacher professional learning (Kennedy 2021). The triple lens theoretical framework is composed of three theories and was built on Kennedy's model to develop a sophisticated approach to understand continuing teacher professional learning. Fraser et al. (2007) perceive that together these theories offer a more formidable structure and a comprehensive, nuanced and multi-dimensional way of examining aspects of professional learning than what they can individually offer.

The triple lens theoretical framework is a combination of three theories: Reid's quadrants (2005), Bell and Gilbert's aspects of professional learning (2005) and Kennedy's models of CPD: A framework of analysis (2005). This triple combination enables analysis of structure and agency from a 3-dimensional perspective: conceptual, analytical and organisational. This was critical for my study which required me to generate and analyse data regarding FET Grade 12 mathematics teachers professional learning contextually through research questions, and analyse and organise the findings through descriptions.

Kennedy's models of professional learning: a framework for analysis enabled description of the nature of the FET Grade 12 mathematics teachers professional learning through teaching roles while at the same time drawing from Villegas-Reimers's (2003) characteristics of professional learning and development. Reid's quadrants identified the spaces of professional learning, while Bell and Gilbert's domains of influence enabled examination of the impetus for these teachers to engage in professional learning activities. The contribution of each theory in the theoretical framework gave a conceptual view of where they learn, how they learn and why they learn. The triple lens theory, thus, guided the data generation and analysis process in addressing Question One on the nature of FET Grade 12 mathematics teachers' professional learning.

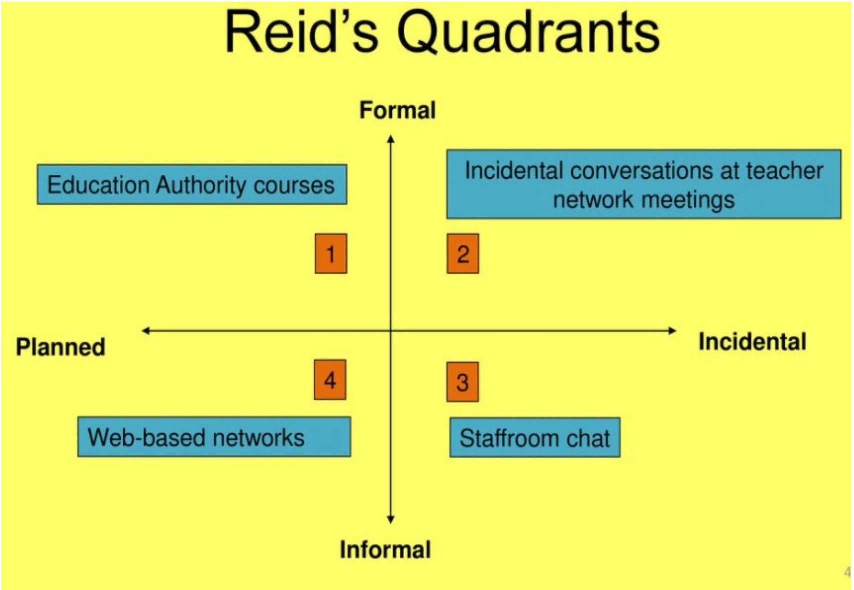
Ball et al.'s (2008) MKT theoretical framework enabled identification, description and explanation of the kinds of knowledge the FET Grade 12 mathematics teachers gained and how the learning influenced their classroom practices in answer to Question Two and Three of the study.

Reid's quadrants of teacher professional learning

Reid's quadrants within the triple lens theory were used to identify and determine how opportunities for professional learning of FET Grade 12 mathematics teachers occur. This was in relation to realms of formal or informal, planned or incidental learning. According to

Reid the spheres of action consist of four quadrants which comprise two dimensions of formal/informal and planned/incidental professional learning opportunities as shown below (Mckinney 2005).

Figure 2.1 Reid's quadrants/Spheres of action



Adapted from (Fraser, Kennedy, Reid & McKinney, 2007)

The quadrants represent the principles upon which professional learning was examined and analysed. Formal opportunities are those that are organised by an agent other than the FET Grade 12 mathematics teachers themselves, such as workshops, meetings or seminars planned and conducted by stakeholders or teacher organisations. On the other hand, informal professional learning opportunities would be those sought and established by the FET Grade 12 mathematics teachers themselves, such as networking or sharing an experience on WhatsApp or other media forms. The formal aspect would include formal programmes provided by institutions. Such learning would offer bankable, credit-bearing opportunities leading to certification such as the Advanced Certificate in Education (ACE) or Post Graduate Certificate in Education (PGCE). The planned opportunities may be formal predetermined and arranged, such as subject meetings to discuss some professional aspect of their work. Incidental opportunities would be informal, those that are spontaneous and unpredictable (Fraser et al. 2005), for example, professional discussion with a colleague in a bus. Contrary to the understanding of non-formal, informal and incidental learning opportunities as offered on Reid's quadrants, Mukeredzi (2009; 2013) discovered that informal learning opportunities sit at the verge or margins of formal and non-formal activities as teachers take advantage of such opportunities to share knowledge. She went on to define non-formal opportunities as planned, organized and structured either internally or externally by the school (for example workshops and meetings) but which do not directly contribute to certification; and informal opportunities as incidental professional learning opportunities where teachers can pick up learning from, for example, collegial interactions during tea break. Thus, in this study, these ideas, including those from Reid's quadrants, were used to determine the nature of professional learning opportunities and experiences that FET Grade 12 mathematics teachers engaged in within their schools or outside, in wider professional learning sites.

Bell and Gilbert's aspects of professional learning

Bell and Gilbert's model of professional learning comprises personal, social and occupational aspects of professional learning known as 'domains of influence' (Kennedy et al. 2013) which prompts a desire for teachers to learn (Bell and Gilbert 2005; Clarke and Hollingsworth 2002). In other words, this helped to determine whether the FET Grade 12 mathematics teachers were prompted to professionally learn by personal desires, influenced by others or prompted by work requirements. The model can be explained as follows:

Figure 2.2: Bell and Gilbert's aspects of professional learning

FRAMEWORK	***Terms of categorization***	***What is to be categorized?***
Bell & Gilbert's three aspects of professional learning.	• Personal (beliefs, values, attitudes, interests & motivation • Social (relationships, individuals, roups & contexts) • Occupational (links between theory & practice, intellectual stimulation & professional relevance	**Domains of influence** of professional learning

Adapted from (Fraser, Kennedy, Reid & McKinney, 2007)

Drawing on the triple lens, Bell and Gilbert's aspects – personal, social and occupational – provided the guiding principles for examining and analysing FET Grade 12 mathematics teachers' motivations to engage in professional learning. The personal aspect suggests that the impetus for change originates from the individual's attitude, experiences, motivation and ownership of learning opportunities where choice and control determine individual engagement with learning opportunities (Institute for Learning Innovation, 2002). This could be engaging in professional learning for promotion, teaching effectiveness or personal knowledge acquisition.

The social aspect suggests engagement in professional learning prompted by the influence of individuals or colleagues in communities of practice manifesting through collegial collaboration, shared beliefs, development of personal or professional identities (Fraser et al. 2007). Such professional learning of FET Grade 12 mathematics teachers may boost self-esteem to relate better with colleagues or encourage them to belong to a professional organisation, for example, a mathematics association.

The occupational aspect relates to professional learning that is stimulated by a desire for intellectual and professional relevance as an individual FET Grade 12 mathematics teacher. Often this is learning to keep pace with reforms and transformation, such as learning a new curriculum or to use a computer. This theory indicates that continuing professional learning is propelled by the individual's perception of their personal, social and professional demands. Bell and Gilbert's theory was employed to understand the nature of FET Grade 12 mathematics teacher professional learning but specifically to understand the motivations behind their professional learning.

Kennedy's models of CPD: A framework for analysis.

Kennedy's (2005) professional learning theory, the third lens of the triple lens theory, identifies nine models of teacher continuing professional learning. The models classified according to how teachers experience their professional learning include the training, award-bearing, deficit, cascade, standard based, coaching/ mentoring, community of practice, action research and transformative models, as illustrated in Table 2.1 below.

Table 2.1 Kennedy's Models of CPD: A framework for analysis

Model of CPD	Purpose of model	
The training model The award-bearing model The deficit model The cascade model	Transmission	
The standards-based model The coaching/mentoring model The community of practice model	Transitional	Increasing capacity for professional autonomy
The action research model The transformative model	Transformative	

Adapted from Kennedy (2005: 248)

The nine models of CPD were further analysed and grouped into three categories: the transmission, transitional and transformative, according to how teacher engagement in professional learning increased their capacity for professional autonomy. Transmissive professional learning emanated from a need to prepare teachers for reforms in education and involved taking teachers through prepared learning materials by an expert. Transmissive learning is usually a presenter or teacher-centred approach to passing information in which the presenter is the dispenser of knowledge, the arbitrator of truth and the final evaluator of learning. Participants are regarded as empty vessels (Garrett et al. 208). This one-way approach, is often ineffective as there is no active audience participation. Such approaches are often prevalent during workshops, meetings, seminars and conferences that teachers attend in their roles. Kennedy's second model – transitional – depicts a situation where teachers collaborate and learn from and with one another. In the context of this study, this could be in situations where the FET Grade 12 mathematics teachers professionally learn through IQMS or cluster meetings. The transformative learning model of professional learning implies personality changes or changes in the organisation of the 'self' which is usually taxing/demanding, as it changes the personality or identity of an individual and is often profoundly significant to the learner (the FET Grade 12 mathematics teacher) (Christiansen et al. 2019). Given that this type of learning involves simultaneous restructuring of individual mental schemas and patterns, a change in attitudes and views involving the three learning dimensions, content, incentive and environment, this method is considered the most effective. Such learning involves inquiry such as analysing learners' performance after a written test then using the findings to decide on new teaching and learning strategies.

These three theories complimented one another to explore aspects of 'how' these teachers experienced professional learning, that is, informal, formal and non-formal (Reid) during social, occupational and personal influences (Bell & Gilbert) through transmissive, transitional and transformative means (Kennedy). Also, the close linkage of research questions also led to the choice of using the three theories to address the how and why professional learning occurs.

Weakness of the triple lens theory

The triple lens theory is seen as bearing a weakness of using "a little out-dated terminology" where readers may relegate it in favour of current terminology (Kennedy 2014: 6). Kennedy identifies such terms as ‘action research’ which have been relegated in favour of ‘professional inquiry’ and ‘communities of practice’ which are commonly referred to as, ‘learning communities’ or ‘teacher learning communities.’ Regardless of the out-dated terminology, the theoretical framework is still worth the salt and it was for this reason that I adopted it in this study. Also, Reid’s spheres of action were limited in exhausting the analysis of findings regarding opportunities for professional learning emerging from experiential and non-formal spaces and to manage the gap it created. Consequently, I roped in Mukeredzi’s (2013; 2016) conceptual frameworks alluded to earlier in this chapter.

Notwithstanding the effectiveness of the triple lens theory to help understand and unpack data addressing how the FET Grade 12 teachers engaged in professional learning through teaching roles, another shortcoming of the theory is that it could not help address the kinds of knowledge gained and how those knowledges influenced teacher classroom practice. Consequently, I had to get a complementary theory: Ball, Thames and Phelps’s (2008) mathematical knowledge for teaching theoretical framework.

Ball, Thames and Phelps’s (2008) mathematical knowledge for teaching theory

Mathematical knowledge for teaching (MKT) propounded by Ball et al. (2008), emanates from Shulman (1987)’s construct of pedagogical content knowledge (PCK). While Shulman views PCK as dependent on the bases of content, pedagogy and context, other researchers (Gess-Newsome 1999, Siverman and Thompson 2008) suggest that these bases were developed separately and the act of teaching integrated them. This is due to conceptions that mathematics teachers exhibit weaknesses and lack a deep conceptual understanding of mathematics (Ball et al. 2005; Hill et al. 2008; Ma 1999; Tsao 2005). This led to Ball et al. (2008) developing the mathematical knowledge for teaching (MKT) theory.

According to Ball et al. (2005; 2008) the MKT types of knowledge are structurally organised into two major domains of knowledge, with other subsidiary domains of knowledge that mathematics teachers need to be effective in their roles. The two major knowledge domains are subject matter knowledge (SMK), which is the knowledge of mathematics content, and pedagogical content knowledge (PCK) which is the knowledge of mathematics content and its teaching. SMK is composed of common content knowledge, mathematics at the horizon and specialised content knowledge. Common content knowledge is knowledge and skills of mathematics used in general settings which is not specific to teaching. This study investigated whether the FET mathematics teachers learnt to solve mathematical problems, understand the content they teach or were able to use terms and notations correctly. Horizon content knowledge relates to knowledge of integrating concepts in mathematics and making mathematics relevant to life and includes the knowledge of the vertical and lateral curricular. For this category of mathematics knowledge, the study sought to discover how FET mathematics teachers learnt to integrate topics in mathematics and link content from one grade to another.

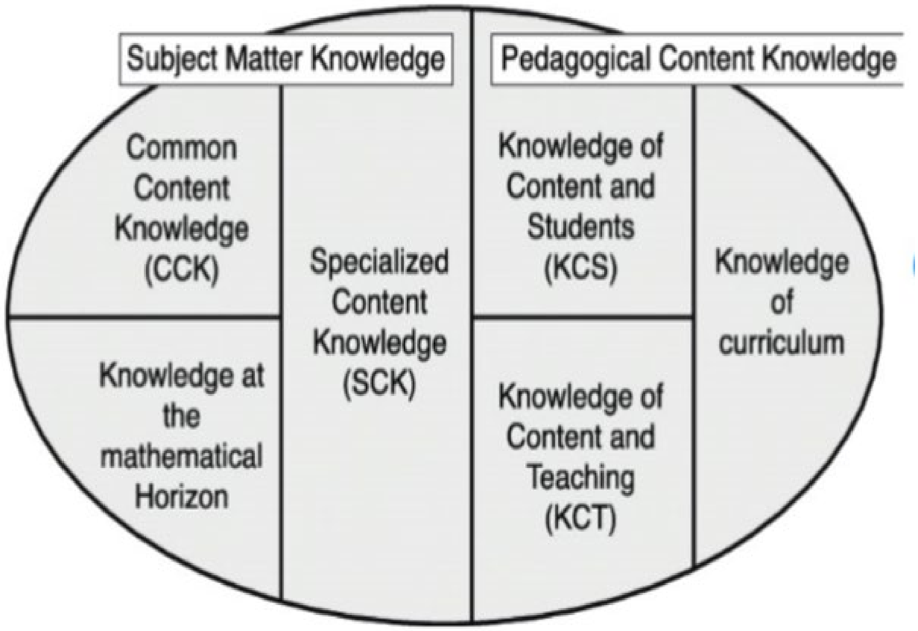
Specialised content knowledge involves knowing the mathematical skills and knowledge particular to teaching mathematics. Specialised content knowledge is the mathematical knowledge and skill especially needed for the teaching of the subject of mathematics (Hurrell 2013; Hill et al. 2008). This type of knowledge enables distinction between good and bad teachers in mathematics and also distinguishes a mathematics teacher as a professional rather than a pedagogue. It involves unpacking of mathematics in a manner that those who are not mathematics teachers are unable to do. In this domain, teaching requires knowledge beyond that which is taught to students (Hill et al. 2008), hence, the need for professional learning. My study sought to determine whether FET Grade 12 mathematics teachers had learnt how to present mathematical ideas to learners and respond to learners' questions in the classroom from their professional learning. In other words, the study sought to explore whether FET mathematics teachers had acquired any unique knowledge and skills as mathematics teachers from their professional learning.

PCK consists of the knowledge of content and students, the knowledge of content and teaching and the knowledge of content and curriculum. The knowledge of content and students is knowing about students and mathematics, where knowing students' perceptions and attitudes about certain topics or concepts in mathematics enables the teacher to break down content to make learning accessible to learners. In this regard, I sought to understand whether FET mathematics teachers understood their learners as they taught them.

The knowledge of content and teaching is about knowing the mathematics one teaches and knowing how to teach it. My study explored whether these teachers in their professional learning learnt to select effective representations to illustrate content during teaching. The knowledge of content and curriculum relates to knowing topics in the curriculum and understanding how those topics relate to each other. The knowledge of content and students demands that teachers must combine their knowledge of content and knowledge of students in lesson preparation and delivery. In other words when FET Grade 12 mathematics teachers teach, they must anticipate what their learners are likely to think and what they may find confusing (Hurrell 2013) leading to calculated choices of tasks and responsibilities for teaching purposes.

The knowledge of content and teaching combines knowing about teaching and knowing about mathematics. The work of teaching mathematics requires one to have mathematics knowledge as well as the appropriate design for teaching the mathematics (Ball et al. 2008). These domains (SMK and PCK) of mathematical knowledge for teaching are peculiar to the teaching of mathematics. They are represented diagrammatically in Figure 2.3 below.

Figure 2.3: Dimensions of mathematical knowledge for teaching (MKT).



Adapted from Ball, et al. (2008: 403).

This theoretical framework was used to categorise the knowledge FET mathematics teachers gained from their professional learning. The different kinds of knowledge in the MKT were guiding principles in analysing and explaining findings. On the other hand, the knowledge of content and teaching was perceived as belonging to general pedagogical knowledge (GPK).

However, this theoretical framework does not include general pedagogical knowledge, a common knowledge domain vital for teachers. This was a weakness. For this reason, I had to draw on conceptual frameworks from Grossman (1998) and Cogill (2008) who include general pedagogical knowledge as one of their key domains of professional knowledge for teaching. GPK is defined by Sothayapetch et al. (2013: 86) as the “broad principles and strategies of classroom management and organisation that appear to transcend subject matter.” This domain includes knowledge of child development and learning, assessment and educational contexts and purposes: in the other words, general knowledge of teaching.

CONCLUSION

The review of studies international, regional and national were examined and critically analysed with reference to concepts derived from research questions set out for this study. The first research question sought to explore how FET mathematics teachers engaged in professional learning through teaching roles. Studies reviewed from the three contexts indicated that teachers experienced professional learning through practice, experience, observation, interaction, reflection, collaboration, use of technological resources, consultation and problem-solving. Drawing from these findings, professional learning was seemingly founded on principles of the deficit model (Kennedy 2005) to solve teacher challenges in their roles. These professional learning opportunities emerged during instruction, curriculum change processes, workshops, seminars and exchange visits between schools. While some studies (Mtetwa et al. 2019; Mhakure 2019; Chirinda and Barmby 2016) identified professional learning that occurred through social networking and sharing information in school corridors, such learning apparently did not attract recognition. Thus, professional learning emerged as formal (in schools and universities) and non-formal (planned, structured, resourced and acknowledged), rather than informal or accidental activity.

The studies generally adopted a qualitative approach and generated data through interviews, focus group discussions, observations, video and audio recordings and document analysis. However, a few of the studies used the quantitative approach and generated data through questionnaires and experiments (Komba and Nkumbi 2016; Mtetwa et al. 2019). The successful use of interviews and focus group discussions in these studies prompted the adoption of these methods of data generation in my study.

The second research question sought to explore kinds of knowledge mathematics teachers gain from their professional learning. The literature reviewed indicated that teachers gained SMK and GPK, PCK, knowledge of learners and knowledge of contexts (Ball et al. 2005; Cole 2011; Mukeredzi 2013; Wanjala et al. 2015). Other forms of knowledge gained included knowledge of processes leading to wrong answers in problem-solving, reflective practice (Reid and Reid 2017), learner diversity and background, learners' emerging incomplete thinking, teaching multiplication, computer application technology and practical knowledge (Mills 2017; Labuschagne 2016; Cereseto 2016). These forms of knowledge gained seemed to equip teachers for practical experiences during instruction and developed their technical skills for handling learner challenges during the teaching and learning processes. Thus, professional learning emanated as a sharpening tool for teacher competence and effectiveness, hence, for professional growth.

The third and last research question attempted to establish the ways in which professional learning influences teachers' pedagogical practices. Reviewed literature showed that professional learning influenced teachers' confidence, self-esteem, teaching theories, pedagogies, strategies, thinking skills and processes (Colbert et al. 2011; Postholm 2018; Payne 2018), identification of teaching gaps, teacher reflection, beliefs and practices, lesson organisation and planning, classroom interactions and action research skills (Coffie 2019; Abdulrazak 2020; Hadebe-Ndlovu 2016; Chiponga and Mutodi 2019). These findings seem to indicate that teachers who engage in professional learning remain astute and well placed for emerging educational practices and challenges. Through these findings, teacher professional learning seems to have been portrayed as the means to professional growth and professionalism. However, it was discovered that professional learning initiated by teacher leaders did not influence teachers' pedagogical practices (Tsotetsi 2013), as it was generally inconsistent with prevailing classroom challenges and needs.

The theoretical frameworks adopted for this study were triple lens theory (Fraser et al. 2007) and Ball, Thames and Phelps's (2008) mathematical knowledge for teaching theory. The triple lens in this study examined the nature of professional learning. Ball et al.'s (2008) theory enabled analysis and presentation of the kinds of knowledge gained by FET mathematics teachers and how this knowledge influences the practice of teaching in their roles. The two theories complemented each other and enabled a nuanced understanding of FET Grade 12 mathematics teacher professional learning. From the findings, these theories enabled me to unpack, understand and describe the data generated. The theoretical frameworks were discussed covering their historical background, principles and application in the study, as well as their weaknesses. However, the weaknesses observed were overcome by inclusion of conceptual frameworks (Cogill 2008; Grossman 1998).

The next chapter discusses the research design and methodology adopted for this study.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

Introduction

This study is an exploration of Further Education and Training (FET) Grade12 mathematics teachers' professional learning through teaching roles and how the learning influences their pedagogical practices. The focus is on qualified practising FET Grade 12 mathematics teachers in one District in the Eastern Cape Province of South Africa. In this study professional learning through teaching roles is viewed as learning for the individual (Stavenga de Jong et al. 2006) which requires no teacher but is mainly a knowledge construction process of the individual's experience (Russell 1988).

The previous chapter started by critically reviewing relevant literature from the global, regional and national contexts. The chapter then unpacked the theoretical lenses adopted for guiding data generation, analysis and explaining findings that addressed the major research question through its subsidiary questions.

This chapter, the research design and methodology chapter, is a narrative of the processes of data generation and analysis.

The subsidiary questions that the research sought to answer are:

1. How do FET Grade 12 mathematics teachers engage in professional learning through teaching roles?
2. What kinds of knowledge do these teachers gain?
3. In what ways do the teachers say their learning influences their pedagogical practices?

The chapter commences by defining the concept of a research paradigm and its assumptions: epistemological, ontological, axiological and methodological assumptions. This is followed by a discussion on the interpretive paradigm upon which the study is grounded. There follows a description of the case-study design and qualitative approach adopted for this study. Following this, population, sampling procedures and sample are outlined. This is followed by a description of the research setting, followed by steps adopted to gain access to participants. The next section discusses data generation procedures. There follows a description of the steps followed in analysing the data. Subsequent to this are issues of trustworthiness discussed under credibility, transferability, auditability, and confirmability, followed by a description of ethical issues that were observed throughout the study. The chapter is tied up by a conclusion. The next section discusses the concept of paradigm.

Research Paradigm

A paradigm is a structure composed of beliefs, values and methods that basically outline the researcher's worldview within which research is conducted (Mackenzie and Knipe 2006). It is the basis upon which a researcher perceives, thinks and understands the phenomenon under investigation which influences the manner in which they generate, interpret and make meaning of the data (Grix 2004). In the context of this study, the paradigm was the guiding principle which determined how I selected and prepared data generating instruments, it influenced how I set up the process of data generation and how to analyse the data. Scholars (Kivunja and Kuyini 2017: 26) define a paradigm as "the thinking or school of thought or set of shared beliefs that inform the generation, meaning and interpretation of research data". A similar definition is offered by Rehman and Alharthi (2016: 51) who say, "A paradigm is a basic belief system and theoretical framework with assumptions about … our way of understanding the reality of the world and studying it". It is the philosophical orientation of the researcher which has the potential to influence the identification and conduct of a study (Aliyu et al. 2015). Similarly, Creswell (1998) and de Vos et al. (2002) concur that a paradigm is a model or frame of reference, a set of assumptions and or beliefs that guide research. Informed by these definitions, a paradigm in this study was perceived as interpretive guiding how I conceived research on the nature of FET mathematics teachers professional learning through teaching roles and that shaped my procedures of acting on and around this key question. The paradigm, therefore, reflects my beliefs and principles guiding the path of thought regarding the methodology adopted for the research process. In other words, a paradigm in this study offered me a body of knowledge that formed some background for understanding the FET Grade 12 mathematics teachers' professional learning through teaching roles, the kinds of knowledge that they gained and the ways in which the teachers said the learning influenced their pedagogical practices. Thus, the paradigm pointed me to where to look for answers to my key question as it was the supportive structure, framework or pointer to assumptions which guided me through the research activities. The assumptions related to epistemological, ontological, axiological and methodological assumptions. These are discussed in the following section.

Epistemology

The term ‘epistemology’ is derived from the Greek word ‘episteme’ which means knowledge (Denzin and Lincoln 2000). This is the theory of knowledge, the philosophy of knowledge, or the “how we come to know” (Mukeredzi 2009). In other words, epistemology is founded on the notion that the way we know what we know becomes the basis for searching for new knowledge (Cooksey and McDonald 2011). In the current study, the way I came to know how FET mathematics teachers engaged in professional learning in their roles was the epistemology. Epistemology is about the relationship between the knower (researcher) and the knowable (the participants, that is FET mathematics teachers), the relationship of researcher to that which they are inquiring into (Mukeredzi 2009). Epistemological assumptions, therefore, address such questions as, ‘how do we come to know, where does the knowledge come from, what is its nature, what constitutes it, whose is it, what of it can be studied, understood and represented?’ (Denzin and Lincoln 1994; Mukeredzi 2009). In other words, epistemology is about the distance between the researcher and the participant.

From the Positivist paradigm, knowledge would be “out there’: what the researcher does is to obtain it using rigid scientific methods to observe, measure, quantify, account for and represent it statistically (Mukeredzi 2009). Thus, the researcher maintains some distance from the respondents – the relationship is detached. From the location of my study, located in the interpretive paradigm, epistemology (reality) was a co-construction of researcher and participants based on experiences, perceptions, values and beliefs of the participants. There was interaction with research participants in the process of knowledge/reality construction, the process of coming to know, the process of data generation. Thus, epistemological assumptions from the interpretive paradigm in this study were that there is a close researcher /researched relationship. Distance was minimized through interviews, focus group discussions and photo-elicitation interviews in the process of elucidation of data.

Ontological Assumptions

The ontological assumptions relate to the principles which guide how researchers make sense or reality about the phenomenon being studied (Scotland 2012). It is a belief system which is applied to examine the nature or essence of knowledge, for example, in this study, the nature of the data generated from FET mathematics teachers about their professional learning experiences. The ontological assumptions made by researchers influence their standpoint regarding reality, knowledge or data. Aliyu et al. (2015) conceive ontological assumptions as building blocks of our worldview through answering questions such as 'What is the essence of this knowledge?' which is a fundamental question of being and establishing the nature of reality/knowledge. Such were philosophical questions that I asked before I decided on the methodology for this study.

Thus, such assumptions address views of whether one views reality as a given – external, objectively real, (positivist standpoint) – or views knowledge as socially constructed, subjectively experienced (subjective experiences of the external world) and then expressed through language (interpretivist standpoint) (Mukeredzi 2009). Ontological assumptions answer questions related to whether reality is external, given, objective and real (positivist) or whether it is experienced, socially constructed and subjective (interpretive) (Creswell 1998; Wellington et al. 2005).

In my study, given the interpretive ontological stance to which the study is aligned, contrary to the positivist ontological outlook, reality or knowledge is socially constructed and subjectively experienced as it emanates from human thought and is expressed through language (Mukeredzi 2009). In other words, interpretive ontology views reality here as personal, therefore, subjective and expressed through language. In the same vein, the ontological assumptions for my study view knowledge as experienced, based on human creation which is socially constructed by actors (FET participants) in the research situation and, therefore, subjective. Thus, knowledge is perceived as a social construction based on individual understandings of their situations through social interactions such as the knowledge gained by FET mathematics teachers through experience and interaction with each other in their roles.

Ontological assumptions help the researcher to understand the form and nature of reality as well as knowledge about that reality (Kivunja and Kuyini 2017). These assumptions relate to reality as emanating from asking subjective questions and receiving subjective answers which, consequently, lead to understanding the data from individual perspectives and being able to interpret it accordingly. Scott and Usher (2004) argue that ontology helps the researcher to engage in thought about the problem and establish the significance of the problem and how it can be approached to yield a solution. Thus, ontological assumptions in my study informed the identification of instruments for data generation (individual face-to-face interviews, focus group discussions and photo-elicitation) and the kinds of questions to ask to obtain answers to the research questions posed in Chapter One.

Axiology

Axiological assumptions involve decision making to uphold appropriate and ethical principles of conducting research (Khatri 2020). Axiology enables researchers to define, evaluate and understand what is considered right and wrong behaviour in the research process (Kivunja and Kuyini 2017). In other words, axiological assumptions deal with the function of values/biases in a study. In this study I, thus, had to answer the question, “what is the role of values?” That is, would the FET mathematics teachers as participants in this study be respected and/or the data generated kept in confidence? A qualitative researcher acknowledges that research is value laden and that there are some biases (Creswell 1998). Axiology provides checks and balances through a batch of questions at inception which researchers need to answer regarding the research, the rights of participants, morality and characteristics to be considered (Khatri 2020) in the study. Such questions include the following according to Kivunja and Kuyini (2017): What values will you live by or be guided by as you conduct your research? What ought to be done to respect participants’ rights? What are the moral issues that need to be considered? Which cultural and intercultural and moral issues arise and how will they be addressed? How will the good of the participants be secured? How will the research be conducted in a socially just, respectful and peaceful manner? How will risk or harm whether it be physical, psychological, legal, social, economic or other be avoided or minimised? In this study, these questions served as a frame through which I generated, analysed and reported on the data addressing research operations. Khatri (2020) and Kivunja and Kuyini (2017) explained that the answers to these questions are governed by teleology, deontology, morality and fairness. Teleology relates to the moral obligation of doing what is personally good and desirable. Deontology is based on the understanding that as a consequence the participants, researcher and community will benefit from the research. Morality involves the setting up of moral values that need to be upheld during research, whereas fairness relates to the need to be fair to all who participate in the research project. All these aspects were taken into consideration in this study. These axiological assumptions were declared upfront in Chapter One as a guide for operation during fieldwork in this study.

Methodology

The methodology is the process of data generation which answers to how a researcher can go about generating data to address the research questions (Denzin and Lincoln 2002; Cohen et al. 2008). Methodology refers to the theory of knowledge, how we come to know in a practical sense as opposed to epistemology, which addresses how we come to know in a philosophical sense (Mukeredzi 2009). Epistemology and methodology are as Henning (2005: 3) cited by Mukeredzi (2009) puts it, “intimately related”, one being the philosophy, the other being the practice. Thus, epistemology is the theory of knowing, while methodology is the practice of knowing. Methodology in this context refers to specific methods and techniques, that is, interviews, focus group discussion, and photo-elicitation employed for data generation to enable understanding of the phenomenon (the FET Grade 12 mathematics teachers’ professional learning through teaching roles).

It relates to how the researcher practically makes choices about the research approach, design, methods and procedures adopted in the study to find knowledge about the research questions (Aliyu et al. 2015). These are the conjectures which guide how the researcher sets in motion the data generation process, that is knowing when to start and how to do it. In other words, in this study I had to answer questions such as “What do I do? How do I do it? Why do I do it? When do I do it? Where do I do it? With whom do I do it?”. Thus, the methodological suppositions or conjectures related to how I would carry out the study.

Having discussed paradigm broadly, the next section discusses the interpretive paradigm in which this study is located.

The interpretive paradigm

The interpretive paradigm views reality as co-constructed in interaction to develop subjective meanings and understandings shared socially and developed experientially (Angen 2000). In other words, people build concepts through sharing ideas and experiences with others. This was the case in this study where individual face-to-face interviews, focus group discussions and photo-elicitation were used to share and explore ideas and experiences and make meaning of the FET mathematics teachers’ professional learning. The FET mathematics teachers investigated were experienced practitioners whose meanings, experiences and understandings of their work varied according to who they were and how they understood their professional learning. Therefore, these teachers’ reality or knowledge of their professional learning experiences was subjective, as suggested by the interpretive paradigm. Interpretivists view reality as socially constructed, context and time dependent, fluid, dynamic and subject to change in time and situation (Cohen, Manion and Morrison 2008). Consequently, I had to generate data on professional learning experiences through interactive methods with the researched. Further, Goldkuhl (2012) indicates that interpretive approaches rely heavily on naturalistic methods (such as interviewing) and in naturalistic settings. Consequently, I generated data from participants interactively in their respective schools. Given that the study sought to explore professional learning of FET mathematics teachers from their perspectives, the interpretive paradigm was appropriate for the study. Next, I discuss research design.

Research Design

A research design is generally understood as some pattern or plan adopted by the researcher to obtain evidence that answers the research questions. Creswell (2008) calls it a plan or proposal to conduct research, which brings together philosophy, strategies of inquiry and specific methods. The nature of my study which explored professional learning experiences, located it in a case study design where focus group discussion, interviews, and photo-elicitation were employed as data generation strategies. This was a case study of FET mathematics teachers in the Eastern Cape Province in CHE district. A case study is an inquiry which investigates a phenomenon in its real-life context, especially when boundaries between what is studied and its context cannot be separated (Schell 1992; Crowe et al. 2011). The professional learning of FET mathematics teachers through teaching roles could not be separated from their teaching experiences and settings. Similarly, Yin (1994:13) defined a case study as "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 … [and] relies on multiple sources of evidence". This definition (Yin 1994) identifies three factors that distinguish a case study from other research designs, that is, empirical inquiry and reliance on multiple evidence. These factors suggest that a case study explores the phenomenon deeply and seeks to provide answers to 'how' and 'why' questions about the study through varied sources. Multi-modal sources of evidence such as focused group discussions, individual face-to-face interviews and photo-elicitation were employed to enable deep exploration of the phenomenon. The case in this case study was professional learning of FET Grade 12 mathematics teachers in their roles, what they learned and how the learning influenced their pedagogical practices. This was also a case of teachers who had experienced poor learner performance and practiced in generally poor environments.

The case study design was, therefore, preferred above other designs for enabling in-depth, multi-faceted explorations of complex phenomena in their real-life settings. These explorations were consistent with Schell's (1992) argument that case studies are suitable for addressing the 'how' and 'why' questions of a study. Schell further argues that case studies are more appropriate where the researcher has little control over events of the phenomenon under investigation, which was the case in this study. Further, the case study design was adopted for the current study because of its relevance in capturing and understanding events in their natural state (Crowe et al. 2011) and in their natural settings, in this case in their schools. Above all, the case study was relevant to this study as it was aligned to the paradigmatic assumptions and orientations adopted for the study.

Qualitative Approach

This study adopted a qualitative approach aligned to the interpretive paradigm. Christensen et al. (2015: 46) describe qualitative research as an, "interpretive research approach relying on multiple types of subjective data and investigation of people in particular situations in their natural environment." This study generated data from teachers in their schools taking advantage of their varied settings in order to get data related to their peculiar situations and employed multiple methods of data generation. The qualitative approach is based on non-numerical data. In qualitative research, "not everything that can be counted counts, and not everything that counts can be counted" (Einstein 2011:11). The opinions, views, experiences and perceptions generated from the FET mathematics teachers were not quantifiable nor could they be counted or expressed statistically as they were subjective. Rather, they required critical analysis of behaviours, as well as interpretations, and presentation through thick descriptions rather than numerical representations. This is elaborated by Paton and Cochran (2002) who view qualitative research as characterised by some aspect of social life and methods which employ words rather than numbers as data for analysis. This study, thus, depended on verbal descriptions of FET mathematics teacher professional learning through their teaching roles. Qualitative research is used to gain an understanding of underlying reasons, opinions and motivations. It provides insights into a problem and also helps to develop ideas (Wyse 2011). Informed by these attributes of qualitative research, the current study sought to explore FET mathematics teachers' opinions, thoughts and beliefs to understand how they experienced professional learning in their roles. Further, a qualitative approach is generally used to discover trends in thought and opinions and usually uses a small sample size (Miles et al. 2014). The advantage of the fact that qualitative research uses a small sample (de Vos 2005) was favourable, as it enabled deep exploration and understanding of this phenomenon through the in-depth face to face interviews, focus group discussions and photo elicitation as data generation techniques (Christensen et al. 2015). The current study used a fairly small sample of only twenty-six FET mathematics teachers.

Qualitative research also gives an opportunity to observe, record and interpret non-verbal communication as part of respondents' feedback during interviews and discussions (Dunleavey et al. 2009; Gill et al. 2008). The focus group discussions, face-to-face individual and photo-elicitation interviews employed were all audio-recorded and this enabled observing and capturing non-verbal cues and communication. Concomitantly, qualitative researchers value multi-modal approaches (Strauss and Corbin 1998). This aspect facilitated triangulation of focus group discussions, individual face-to-face and photo-elicitation interviews to explore the phenomenon from diverse participant perspectives. The value of the multi-method approach lies in the complementary nature of data generated through multiple methods. In this study, apart from enabling data generation methods to filter one another, as shortcomings of one are complemented by strengths of the other, this reduced method boundedness (Mukeredzi 2009). In addition, employing multi-methods minimises exclusive reliance on one and gives a more nuanced picture of the reality under exploration. The subsequent section discusses the setting from where the research was conducted.

Research Setting

This section describes the research setting to offer a clear understanding of the context in which data were generated, analysed and explained. The study was conducted in the educational district of CHE. CHE is a pseudonym adopted for the district under study. While the acronym might be taken to mean Council of Higher Education, these are letters chosen in honour of my family representing the first letters of names of my siblings. There were twenty-six senior secondary schools in CHE District (See Figure 3.1 below) from where one participant per school was extracted.

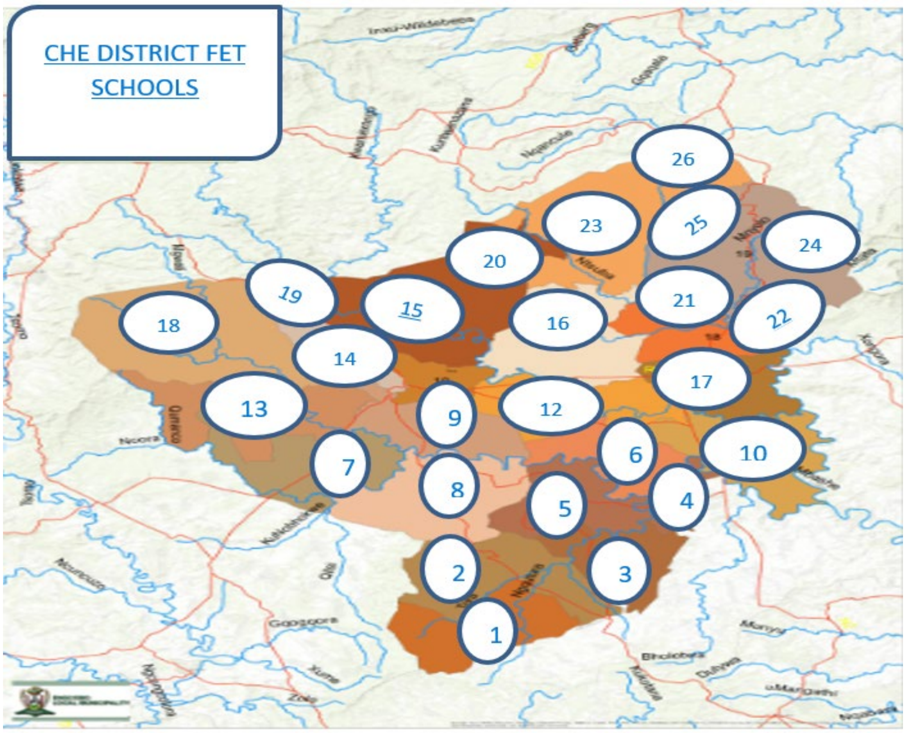
Physical Infrastructure

CHE district, in the former Bantustan state of the Transkei (Aliber and Xobadiya 2020), is centrally located in the Eastern Cape Province. It is generally mountainous, rural, densely populated and characterised by vegetable farms that employ the rural folk. Due to uneven terrain, schools are far apart, consequently, some learners walked more than thirty kilometres to the nearest school (Damba-Hendrik 2020).

The schools are generally linked by gravel roads. Notwithstanding that they are well maintained, they are often impassable during wet weather. Teachers live in local towns and commute to and from work in shared transport. While shared transport creates space for professional learning, as teachers often use such opportunities to learn from each other, Catt (2020) explains that teachers usually arrive late and leave early, compromising teaching/learning time. Time for relaxed in-school professional learning is, therefore, limited.

Figure 3.1 reflects the 26 schools in the CHE district in which the study was conducted. Out of these, nineteen are post-apartheid rural senior secondary schools which have non-permanent structures, but are built of pre-fabricated material. While learning space is available, there is no office space. Often, classrooms would be converted to open offices.

Figure 3.1*: Research Setting Map of CHE district.*



Engcobo Local Municipality (2016)

Key: Rivers
Gravel road

Numbers 1 to 26 represent the Research sites

The open office accommodation was broadly beneficial for interaction but also hindered teacher privacy and opportunities for departmental professional learning engagements. Thus, professional learning within the schools generally occurred through individual efforts, staff meetings, Cluster and District workshops. There are generally two toilet blocks, one for girls and one for boys, and staff toilets are compartments separated from the learners' toilet blocks.

There is no piped water: the schools depend on rain water harvested in tanks. With all these challenges some rural schools are so bad that the picture portrayed is not enticing for a teaching career or for living (Mukeredzi 2021). Mukeredzi concurs with other studies (du Plessis 2017; Hlalelo 2014; Myende and Chikoko 2014) that schools in South African rural areas are affected by social problems like inadequate facilities and services, disease and poverty, as well as reduced self-efficacy for teachers working there which tend to demean their self-esteem. The problems of geography seemingly make the teachers live in isolation which does not promote professional learning. Ali et al. (2016) argues that teacher isolation causes burnout and a state of helplessness which stimulates their desire for collaboration. In this regard, these teachers had an affinity to professionally learn from colleagues both in their and other schools.

Seven of the schools were situated in serviced towns which provided facilities and services (House of Commons Library 2018) like tarmac roads, piped water, flush toilets and electricity. Classroom and office accommodation are adequate and furnished with wi-fi, courtesy of Vodacom who also provide tablets for learners. However, such technological artefacts were lying idle due to lack of skills of both learners and teachers and this limited teacher engagement in on-line professional learning. However, teachers in these towns could easily meet and share work experiences or hold meetings which promoted professional learning.

Size and type of schools

The schools are generally small with only one or two FET Grade 12 mathematics teachers per school. This limited in-school collaborative professional learning. Although all the schools are FET phase schools, some offering Grades 8-12, others offer only Grades 10-12 making them very small. The average enrolment is 300 learners and generally there is a staff complement of nine teachers and a teacher-pupil ratio of 1:33 (ECDoE 2019; DBE 2018).

South African schools are categorised into quintiles: one-five. All the schools in CHE District were in quintiles one-three except for one school which was quintile five as it was a former Model C school. Quintiles were created by Statistics South Africa to divide schools according to their location and the socio-economic status of the population to which they belonged

(DBE 2013). Thus, Quintiles one-three are non-fee-paying, located in poverty-stricken areas, while quintiles four-five are fee-paying schools in wealthy communities, generally former apartheid Model C schools which were formerly only attended by white children (Roodt 2011). Such schools are well resourced: they have libraries and adequate learning and office accommodation. The set-up seemingly promoted teacher non-formal and informal professional learning. While such schools, following liberation in 1994, became multi-racial, they continued to enjoy better teaching and learning facilities (Roodt 2011) which promoted professional learning.

The 19 rural schools are government funded and can decide on how to use allocated funds following guidelines and procedures for financial and procurement management (Barberton et al. 2017). School enrolments determine the total fund allocated at R31 per learner annually (DBE 2020). However, the funds received by schools are generally inadequate, hence, rural schools are always under-resourced which compromises teacher engagement in planned professional learning through cluster meetings, inter-school visits and inter-school exchange programmes which need funding. To complement the meagre funds, these schools are financially supported by School Governing Boards (SGBs), parents' committees which represent the parental component in school governance. However, given the poor economic status of rural parents, very few are able to pay the agreed amounts as they depend on meagre social grants from the South African Social Security Agency (SASSA). The next section discusses the process of accessing participants.

Gaining access

Gaining access to and acceptance in the research setting entails obtaining permission that the researcher needs before embarking on the study and the right to go into institutions or organisations where the research is to be conducted (Hedge 2012). Thus, gaining access to research sites and participants was critical for the success of this study. Researchers (Hoyland et al. 2015; Riese 2018) argue that gaining access into research sites influences the research process and results of the study, hence, it must be done successfully. Permission to meet with teachers who participated in this study was sought from the provincial and district offices of the Department of Education in the Eastern Cape through an application for consent of the gatekeepers (See Appendix 4). After successfully defending my proposal before the Departmental Committee, and later Faculty Research Committee (FRC), an application for permission to conduct the study, for Ethical Clearance (EC), was made to the Institutional

Research and Ethics Committee (IREC). Attached to the EC application were the gate keeper consent letters, including permission request letters to school principals, as well as information and consent letters for participants (See Appendix 4). The IREC issued the EC letter (See Appendix 2) for me to commence the study. Permission request letters contained details about the research, including what participants would be expected to do (See Appendix 5) and including ethical considerations to be adhered to.

After meeting the teachers during cluster meetings and identifying participants as explained in detail under sampling, I then presented myself to CHE District schools where the teachers were teaching and where I intended to conduct my study. Calling on the principals, I introduced myself and produced my EC and consent letters from the district and provincial offices. It was only subsequent to these visits that they consented to my meeting their teachers as and when I was ready. I decided to meet them during Subject Cluster meetings.

The population

The population refers to the entire group of interest to the researcher which the researcher studies and from which the sample is generated (Christensen et al. 2015: 509). Gause (2009) views a research population as a well-defined collection of individuals or other objects which is known to possess similar characteristics regarding some phenomena. In this study, the population was made up of all FET Grade 12 mathematics teachers in the Eastern Cape Province – approximately 1 486. These were teachers who were teaching Grade 12 classes at the time of the study and were faced with the challenge of poor matric results. The teachers were teaching the new mathematics CAPS curriculum, and were presumed to be experiencing professional learning through their teaching roles and to be able to share the knowledge they gained and how the learning influenced their teaching. It is difficult to generate data from the whole population and, as Banerjee and Chaudhury (2010) point out, it is tedious to survey the entire population as that causes the research work to compromise its trustworthiness, so sampling was required.

Sampling

Sampling is generally a concept founded on the understanding that it is difficult in qualitative research to use the entire population for generating data. Gentles et al. (2015: 1772) view sampling as, "the act, process or technique of selecting a representative part of a population for purposes of determining parameters or characteristics of the whole population". Thus, sampling is a way of choosing members from a defined population to be included in a study. This study has a sample of 26 FET Grade 12 mathematics teachers. A sample is a “small group or subset of the population” which possesses characteristics of the population under study (Cohen et al. 2008:100). A sample is used to generate data and to get a deeper understanding of whatever issue or topic is of interest to the researcher, thus, in this study to get answers to research questions. Guest et al. (2013) argue that the more a sample resembles the population, the more the researcher can be confident of the quality of the results of their study. There are several sampling techniques used to select a sample in qualitative studies. These include among others convenience sampling, quota sampling, snowball sampling and purposive sampling. Purposive sampling technique was adopted in this study.

Purposive sampling

A purposive sample is achieved when a researcher uses personal judgement to extract individuals with certain characteristics in mind from the population of interest (de Vos 2005). The characteristics that were considered for participation in this study were that participants were knowledgeable FET Grade 12 mathematics teachers. As these teachers were qualified and experienced in their roles, they were considered to be information-rich (Mukeredzi 2009) regarding the phenomenon under scrutiny. This was informed by Palinkas et al. (2016) who advise that purposive sampling is preferred to other techniques in qualitative research for its association with the production of rich data by knowledgeable participants. CHE district was purposively identified because it was always among the least performing districts in Matric examinations in the province (DBE 2016). As such, I wanted to understand from the teachers their professional learning experiences.

To sample the participants, I took advantage of organised cluster meetings to explain my study and identify the participants through the support of subject advisors who provided a programme of scheduled meetings for clusters. At the end of the meeting, I explained my study and requested to meet FET Grade 12 Teachers to whom I put my request for their participation in the study. There were 34 FET mathematics teachers and I wanted 26. I selected that number (26) and reserved the remaining eight (8) for piloting. I then requested for one teacher from each school. Where there was more than one teacher, I requested a woman teacher as there were few female FET Grade 12 mathematics teachers. This is consistent with surveyed literature (Wang and Degol 2017) which shows that women are under-represented in Science, Technology, Engineering, and Mathematics (STEM) careers. Having female teachers would help to maintain gender balance and accommodate diversity of views. In a school where there was more than one Grade 12 teacher, only one teacher was selected based on seniority in terms of teaching experience. In the entire sample there were eight women and eighteen men.

Meeting the 26 teachers after the meeting helped me to ascertain their willingness and availability to participate. This idea was borrowed from Hedge (2012) who advises that people are harder to ignore than faceless emails and telephone calls when recruiting participants for a research project. With the 26 teachers, we then discussed the research further. Following this, I issued the Letter of Information (See Appendix 4) and went through it with them explaining and clarifying each point. After this I requested them to sign a Consent Form (See Appendix 5) and requested them to write down their names, contact numbers and school addresses, as well as directions to get to their schools. I also requested contact details for the eight whom I was going to use for piloting.

From the purposive sample of 26 participants, I further purposively selected 16 participants to take part in individual face-to-face interviews and photo-elicitation. This I did at the end of each focus group discussion. As a mathematics teacher in this district, I understood the environment and, broadly, the individuals who participated in the study although I had not known any of them on a personal level before the study. However, being in the same discipline was helpful when reaching out to establish rapport and in approaching different personalities to set up meetings for data generation.

Piloting

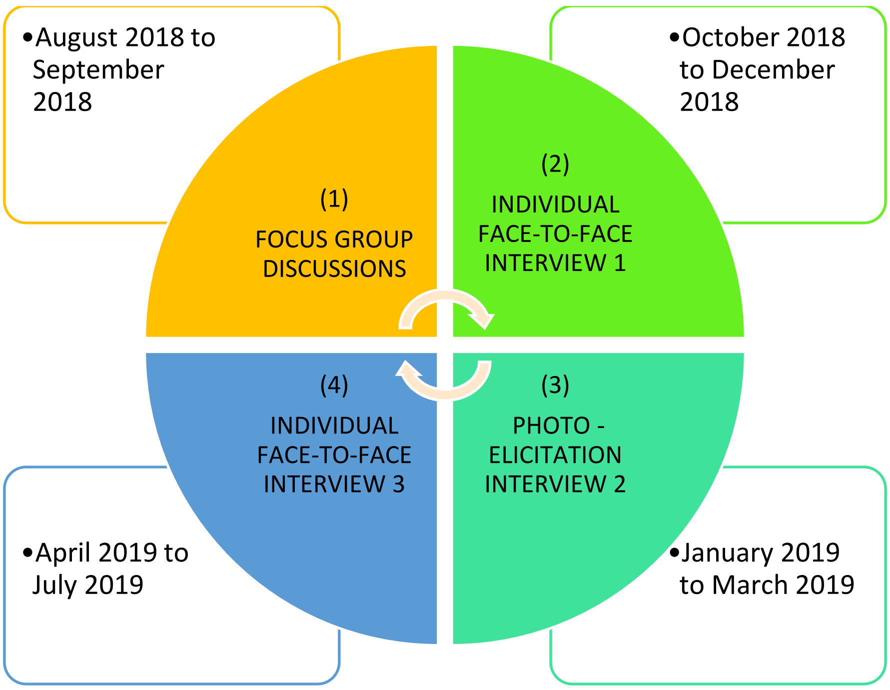
Piloting which was done before the main data generation helped to detect potential barriers in the major fieldwork (Resnick, 2015). Further, piloting helped me to check the required time for the interviews and focus group discussions and the clarity of questions to generate required data. The pilot study was conducted in CE (pseudonym) cluster in the same district but pilot participants were not part of the main study.

I pilot tested instruments with four of the eight teachers who were in excess of the sample (26), and were teaching in schools that were fairly close. As these teachers had attended the cluster meeting, they were already aware of my study. Using their details, I requested to meet with them. This was a convenience sample due to their proximity to me. I consulted the local librarian for a venue to meet the four teachers for pilot focus group discussions and face to face interviews on two consecutive Friday afternoons starting with focus group discussions. All the pilot interviews were audio recorded for transcribing and analysing to determine relevance and adequacy of data in answering research questions. Results from the pilot study were discussed with my cohort peers and my supervisors. Profound advice was suggested from which I reflected on and used to restructure my instruments to make questions clearer. Consequently, this set me ready to commence the main fieldwork for my study. The following section discusses data generation.

Data generation

In this study, focus group discussions, individual face-to-face interviews, and photo-elicitation were used for data generation. This was informed by Canals (2017: 391) who ascertains that the kind of data to be generated "clarifies which methods are most appropriate." The data generation methods captured individuals' in-depth subjective data in its original state (Meo, 2010) and were aligned with the philosophical orientations selected for the study: the research paradigm, research design and research approach. Data were captured from its source, both verbal and non-verbal, as it was and as it occurred. Figure 3.2 below shows the itinerary for data generation.

Figure 3.2: Data Generation Itinerary



Source: Researcher (2021)

From Figure 3.2 the fieldwork was carried out within a period of one complete year, from August 2018 to July 2019 as reflected in the data generation itinerary.

A summary of the particular sessions held with the participants during this period is reflected in Table 3.1

Table 3.1 Data generation

Method	**Focus Group Discussions**	**Interview 1**	**Interview 2**	**Interview 3**	**Total**
Number of sessions	4	16	16	16	**52**

Source: Researcher (2021)

The table shows that a total of fifty-two data generations sessions were conducted. Reference to Table 3.1 will be made throughout the discussion of the process of data generation below.

Focus group discussions

A focus group is a "small homogeneous or heterogeneous group of 4-12 people focused on the discussion of a research topic and issue" (Christensen et al. 2015: 73). In this study focus group interviews involved both heterogeneous and homogeneous group interactions. The nature of grouping was prompted by the fact that there were more men than women teaching FET Grade 12 mathematics as alluded to above and as such one of the groups had men only. During mixed groupings there were diverse opinions which promoted rich data for the study, contrary to the homogeneous group which tended to share similar experiences.

However, focus group discussions enabled me to realise general trends about my topic through interaction and in-depth discussions (Schindler and Sun 2003) with Grade 12 mathematics teachers in the district. The discussions also enabled comparisons of opinions across participants and groups while highlighting issues where these teachers differed or shared common ideas and experiences. Focus group discussion also offered a broad range of responses about the topic from different participants, as teachers had an opportunity to self-check, add on, or dispute colleagues' responses where necessary (Krueger and Casey 2014).

However, it was important to be precautionary, as focus group discussions might result in disagreements and irrelevant discussions which could distract from the focus of the study (Berg et al. 2004; Ennis et al. 2012). I moderated and regulated the discussions to avoid disagreements and irrelevant discussions which could spoil the process.

I held four focus group discussions, two with six participants each, while another two had seven participants each. The focus group discussions were the first source of data. The choice of starting with focus group discussions in this study was underpinned by a number of reasons. Firstly, focus group discussions helped individual participants gather confidence in themselves by creating a feeling that they were not in it alone. Secondly, the focus group interviews exposed individual participants to wider thoughts about the research questions thereby enriching individual responses later on during face-to-face individual interviews. Thirdly, focus group discussions set the tone for my data generation as they encouraged freedom of expression among participants. Fourthly, they also gave me an opportunity to take note of issues to follow up on in the subsequent individual interviews. Fifthly, from these discussions I was able to identify participants for participation in individual interviews. Finally, the discussions helped in mapping the way forward, providing logistical guidelines and setting up appointments for individual face-to-face meetings.

The venue for focus group meetings was at schools viewed by participants as central in the CHE District. Permission to hold focus group meetings and use the schools was sought from principals of identified primary schools. Notwithstanding that the teachers were reimbursed for their transport expenses; these venues were chosen to minimize travelling long distances by participants. The principals were approached through formal requests to use their facility and the documents (EC, Consent letters from Provincial and District Offices) were presented, including a letter of information. The venue request letter spelt out the dates and times for the focus group meetings with the teachers, duration of sessions and request for furniture, such as chairs and a table, that was needed.

A focus group discussion guide was used to keep the interviews focused on the purpose of the study to ensure generation of relevant data to address research questions. The sessions took between sixty and ninety minutes to allow each participant adequate time to share their experiences of professional learning. The discussions were audio recorded to ensure accurate capturing of participants' stories while I jotted down sparse notes.

Informed by Nyumba (2018) and Hennink (2007) who consider the position of a researcher as that of a facilitator or moderator of discussions with participants, I assumed this role and commenced the data generation process with persuasive but simple questions. This was informed by Krueger (2002) who advises that researchers need to create a permissive atmosphere and set the tone for discussion. This process was meant to promote a situation where the data generation was conducive and at the same time produce rich responses consistent with the questions addressed.

I started with simple questions: for example, *please tell me the kinds of activities you do as a FET mathematics teacher?* and gradually moved to more searching ones like, *what are your opinions about teacher professional learning?* I adopted this approach to relax participants and then gently move them into generating more in-depth data, as it were moving them from 'known to unknown'. For every question asked participants volunteered to answer and other participants would come in to support or expand on the answer. Each participant's answer was valued and all participants contributed as there was no wrong or right answer (Krueger 2002).

At the end of the discussion, I summarised the main points to enable participants to confirm what they had said during the discussion. I then explained that I needed to select four of them to participate in individual face-to-face and photo-elicitation interviews.

I purposively selected four of the teachers, consulting my notes and the codes used as pseudonyms in the focus group meeting. The inclusion/exclusion criteria for selecting the 16 participants was determined by their openness and articulation of views, how they contributed to discussion, their readiness to respond, as well as the richness of their responses. Drawing on surveyed literature (Ennis and Chen 2012) that participants are the most important data source in research, verbal eloquence, confidence, precision, clarity, descriptive and analytical abilities were pivotal to the possibility of generating in-depth data. I, therefore, drew this sample based on these attributes. I called out their codes and requested the teachers' participation in the face-to-face individual and photo-elicitation interviews and they were all positive. I thanked them all and informed the extra participants that in case I needed them, I would get in touch and that if they came up with additional data, they could always get in touch with me.

Following this we discussed photo-elicitation and I explained that the participants were to take at least ten photographs each, which depicted their professional learning practices in their roles as teachers. The participants would send the photographs to me through WhatsApp at the first face-to-face interview after which I would print them in readiness for Interview Two – Photo-elicitation. The teachers opted to use their cell phones to take the photographs.

Individual face-to-face Interviews

An interview is a situation where the interviewer asks the interviewee a series of questions for purposes of data generation (Cohen et al. 2008). In this study interviews were an appropriate way of understanding attitudes, perceptions, opinions and experiences of FET mathematics teachers, in other words, their perspectives of their professional learning in line with the philosophical orientations adopted for the study. The interviews put me at a vantage point to elicit relevant and rich data for the topic through probing and following-up on questions (Chadwick et al. 2008). This was appropriate for the study given that the problem under scrutiny required an in-depth understanding of experiences and opinions of FET mathematics teachers' professional learning. Flexibility of questioning that is allowed during individual face-to-face interviews (Cohen et al. 2008), enabled probing for more detailed, relevant and comprehensive data and, where necessary, elaborations and clarifications of questions.

In line with a qualitative approach, the individual face-to-face interviews were conducted in participants' natural settings: their schools where much of the phenomenon, professional learning, occurred in their roles. Holding interviews in participants' natural settings was in line with Seidman (1988) who emphasises familiar context as vital for extracting rich data. Following an interview schedule, questions were asked following the same order with each participant to enable comparisons across participants and building on the responses. Interviews took approximately forty-five minutes to an hour. The interview schedule regulated discussions and ensured focus on the purpose of the study. Given that dependence on participants' words and voices is a typical feature of qualitative enquiry and in particular face to face interviews, and that recording produces complete verbal transcripts, audio recording allowed for capturing of every detail (Mukeredzi 2009) while I jotted sparse notes to attend in full to the interviewee, upholding the flow of conversation.

In this study, I adopted a three-interview series which involved holding three separate face-to-face interviews with each of the 16 participants. This approach was informed by Seidman (1988) who suggests that interview data should involve more than a single interview. Seidman argues that several interviews with one individual on the same subject enhances confirmation of consistency of participants' responses and enables further exploration of other details of the study. The interviews which were held from October 2018 to July 2019 as highlighted in Figure 3.2 above were held approximately within two months of each other to enable confirmation of internal consistency of participants’ stories (Mukeredzi 2009).

Interview One

I started the interview by welcoming and encouraging the participant to relax and be as honest as they could. I reminded the participant about audio-recording the interview while I took down sparse notes in my researcher diary for later retrieval. Mathers et al. (2002) and Kinahan (2017) argue that staging an interview must consequently yield rich data. I asked questions and listened carefully to participants’ stories while at the same time observing their facial expression for non-verbal communication (Fox 2009). Some participants became shy and ran dry of responses, but I quickly added some prompts to relax the situation and simplified the questions without compromising the quality of data required which made the participants gain confidence and move on with the discussions again.

Interview One started by following up on some of the points raised during focus group discussions. The interview explored the activities FET Grade 12 mathematics teachers engaged in inside and outside the school from which they learnt something. For example, I asked such questions as “*Tell me the activities that you do inside the school from which you learn something.”* Further, the interview sought to know what these teachers learnt from the activities they engaged themselves in and how that helped them in their teaching. Questions such as: *What kinds of things do you learn? In what ways does knowing that help you?* were asked. Probing and following up on responses was done to ensure expansion of responses, clarity and a focus on the questions of relevance to the study. This was informed by Fox (2009) and Kinahan (2017) who explain that face-to-face interviews promote a chance for the researcher to probe responses, correct misunderstandings and follow-up ideas and ask questions, such as *Please, tell me more on that? What then happened? What did you do after? What would you say about that experience? How did that happen?* Such prompts, made participants explain and elaborate on responses thereby offering more in-depth data. Responses to all these kinds of questions required careful listening so as to build on the dialogue by extending the questions incrementally. Nodding my head and making verbal sounds like ‘Mmmm’ in agreement also encouraged participants to keep on talking. In some instances, I had to repeat what they said to demonstrate that I was moving with them and that I valued their responses, which also promoted further talking to generate rich data. The next section discusses photo-elicitation.

Interview Two (Photo-elicitation)

Photo-elicitation is a method of interview that uses visual images to elicit comments from participants (Bignante 2010). The method uses a wide range of images in the form of photographs, videos, paintings, cartoons, graffiti, advertising and others (Harper 2002). This study used photo-elicitation because it represented the reality of what actually happened during the period the shot was taken (Warren 2005). Thus, photo-elicitation enabled more in-depth descriptions of professional learning from participants, unlike interviews which had no lead prompts to respond to.

I requested each participant to select at least five photographs out of the ten they presented and use them as prompts for discussing their professional learning. Participants in this study captured those aspects that depicted and represented their professional learning practices in their work life, in other words, how and what they learnt in their roles as teachers. As participants had used their cell phones to take photographs, I reimbursed them R15 for each of the photographs they shot for the discussion for their data bundles. Photo-elicitation enables understandings of how other people experience their work and attracts unique interpretations from the interviewees (Meo 2010) making it ideal for qualitative research. This technique was used to encourage FET mathematics teachers to reflect on and discuss their professional learning in their roles. Thus, photographs in this study provided prompts for critical and analytical dialogue, through exploration of meanings during the interview (Mukeredzi 2009). This pushed the FET mathematics teachers into reflection on and discussion of their professional learning. Participants were prompted to talk more, as they took control of the discussion, articulating their feelings and opinions about their professional learning experiences as those sentiments were directed at something tangible made by themselves (Mukeredzi 2009). Thus, they discussed their teaching life and roles as they saw it, in relation to their professional learning.

This method enabled generation of insights that differ from those obtained in verbal inquiry (Torre and Murphy 2015) and created images that promoted the interview by stimulating and enhancing more direct involvement of the participant (Mukeredzi 2013). Also, the use of photo-elicitation was helpful given that what photos showed was what actually existed in front of the camera for at least the time the camera took to make the exposure (Mukeredzi 2009). Thus, these photographs illustrated things as they really were and how they were experienced given that photographs are representations and not constructions of reality. This is consistent with Glaw et al. (2017: 3) who say, "Photo-elicitation interviews can create deep and interesting talk" as they become a "collaborative effort rather than an individual effort." Notwithstanding the generation of rich data that was enhanced by photographs, there was a need to always guard against losing focus on the study as participants had a lot to discuss about their photographs, some of which was not relevant to research questions. To get rid of such tendencies, I would pose some questions that redirected the discussion towards the intended focus of the study such as*: But what does this mean to you and your professional learning?*

During photo-elicitation interviews, questions emerged from the photographs presented. Questions such as, *What was happening in this photograph? What do you like about this photograph? What do you learn from this photograph?* which were asked addressed my research questions. These and other questions arising in the discussions resulted in deep understanding of the experiences, attitudes and opinions of FET mathematics teachers in their roles. Participants would not get stuck in answering questions about their photographs. Glaw et al. (2017: 3) in support further say, "photographing their own images gives them freedom to choose what they want to talk about in the interview, which makes them more relaxed because they know what the content of the interview will be." Another powerful source of data emanated from these interviews as I observed emotions that arose among the participants when they discussed the meanings of their photographs in relation to their professional learning.

Individual face-to-face Interview Three is discussed in the next section.

Interview Three

This was the last individual face-to-face interview conducted in this study. Although the interview sought similar data as in the first and second interview, it was also intended to make participants reflect on their professional learning and how the knowledge gained influenced their classroom practice. Participants reflected on meanings of their professional learning experiences, the connections between their life as FET mathematics teachers and their roles and how all this contributed to their professional learning within their school contexts in which the learning occurred. The questions asked were open-ended, deliberately designed to capture comprehensive responses from participants (Mukeredzi 2009). Where questions appeared challenging, explanations were given to clarify and capture relevant data.

Member Checking

Member checking involved returning data to participants for them to confirm or edit their stories. This is informed by Birt et al. (2016) who asserts that member checking is a technique for exploring the accuracy and resonance of the data with participants experiences. When I went for Interview One, I carried transcripts of the focus group discussions for participants to member check. Likewise, I did the same thing for interviews two and three. In other words, 16 of the 26 participants member-checked the transcripts and 13 of them listened to their audio-recordings to verify their presentations (Bygstad and Munkvold 2007). It was however not possible to get member checking done by all participants. However, informed by Yin and Lu (2014) and Candela (2019) who view member checking as a process in which the researcher asks one or some of the participants in the study to check the accuracy of the transcriptions, I felt that the member checking done by 16 of the 26 participants was adequate. Further, given that participants were happy that I had captured their responses generally accurately, and in some cases, expanded their responses, there appeared to be no pressing need to seek out the remaining participants of focus group discussions to member check. Engaging in member checking helped me to portray participants responses accurately and reduce the risk of making conclusions based on my personal biases. This was consistent with Creswell and Miller's (2019: 4620) notion that, "member checking provides a way for the researcher to ensure the accurate portrayal of participants voices …"
Like any other fieldwork, there were some challenges that I experienced in the process.

Challenges experienced during data generation

Usually, research of this magnitude is always prone to challenges and mine was no exception. I experienced challenges regarding gaining access, time constraints and logistical issues. Gaining access to research settings (the schools) and participants (the FET Grade 12 mathematics teachers) was a mammoth task caused by bureaucratic tendencies in the Department of Basic Education (DBE) which caused prolonged delays. However, Thammapol et al. (2019) emphasise that gaining access is a major part of the research process. Delays at the DBE also delayed the issuance of EC and the start of fieldwork. The channel to secure such permission pointed at me getting authority from the Head of Department and presenting the authority letter to the District Director and then a permission letter to go to the schools. These were busy officials who would not prioritise my request for permission letters as a matter of urgency. This is confirmed by Liamputtong (2007) who also discovered that negotiating access and gaining entry to the field could be problematic. I remained patient while I pastored the official through telephone calls and sometimes visited them. This was because according to Kondowe and Booyens (2014) successful research depends greatly on how the researcher gains access to the setting. I finally got my permission letters two months later than the intended time for data generation and then presented these gatekeepers letters to DUT for EC application which was finally issued on 14 August 2018. This delay meant revisiting the data generation plan which ushered another challenge of time constraints.

A revisit on the data generation plan meant that I had to shift my working itinerary two months later than the initial plan. This meant starting my data generation in August 2018 instead of 1 June 2018. However, this was not unique as Silverio et al. (2020) argue that qualitative researchers are usually extremely time-pressured but they must avoid compromising stages in their fieldwork. From August, Grade 12 mathematics teachers were extremely busy preparing their classes for Matric examinations and there was generally a scarcity of time for other programmes. This affected me also, as I was busy with preparation for my Matric classes as well, offering daily extra lessons and weekend classes. However, it was better with me because I had some assistant tutors attached to my class from Maths and Science Infinity (MSI) who would take my classes when I had to fulfil some of my research appointments. This was not by design, but rather a coincidence that my school got these tutors and they became a great benefit to me. I had to reschedule appointments with my participants and securing appropriate times for interviews was not easy. However, mathematics was one of the earliest subjects that was written towards the end of October in that year. This eventually opened up opportunities for engaging in interviews as the FET Grade 12 teachers were no longer committed in the classroom. This circumvented leaving some of the planned work untaught which McGrath et al. (2019) referred to as the ‘perils’ of time constraints. Thus, much of the backlog that existed on the data generation plan was cleared and I then proceeded as initially planned.

Challenges related to logistical issues included unforeseen problems and unreliable communication networks. This is consistent with Mukeredzi (2012) who define logistical issues as unanticipated problems including limited communication among others. CHE District, which is situated in a mountainous area with schools connected by gravel roads, was sometimes impassable due to bad weather. In some cases, my appointments were disrupted by snow (August) and/or rain (November and early December) as the roads became slippery and dangerous. In such situations, I would phone my participants to reschedule for the interviews but often found communication networks disrupted. These circumstances were understood by the participants and whenever chance permitted, they always allowed me to reschedule the interviews.

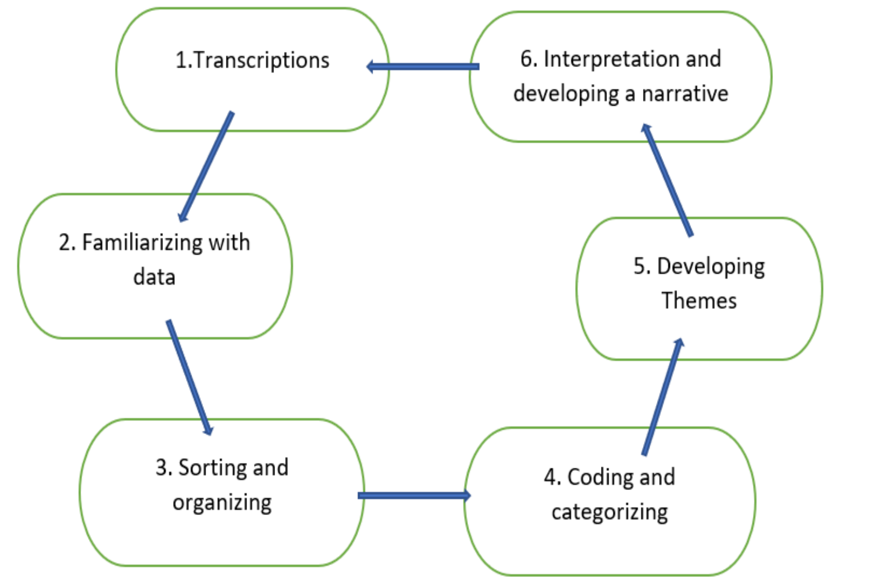
Data analysis

Data analysis "is essentially about detection and the tasks of defining, categorising, theorising, explaining, exploring and mapping are fundamental to the analyst's role," (Ritchie and Spencer 2002:309). It is the purpose for which data are generated in a research situation. Mukeredzi (2009) consider data analysis as what helps in search for patterns and/or ideas to explain the existence of those patterns. In practical terms, it is how we examine and arrange data generated from data generation instruments (focus group discussions, individual interviews, photo-elicitation and notes taken in the field) and sort and filter them into workable units. Data analysis planning is necessary as it considers what the data is for and how the results of the analysis can be verified (Cohen et al. 2008: 86). Since this study generated data in the form of opinions, experiences, perceptions, attitudes and motivations, data analysis constituted coding, categorising and theming through the use of thick descriptions.

Data analysis was in two stages: in-field data analysis and the main post data generation analysis (Mukeredzi 2009). In-field data analysis commenced when I started data generation and continued until the end of the fieldwork. This enabled me to identify patterns that were emerging from the data, while prompting reflection on what was occurring in the field in answer to questions like: what the participants did, how, why when and with whom they did it (Mukeredzi 2009).

The second stage, the post data generation analysis constituted the main data analysis phase that I undertook after completing all fieldwork and capturing of all data to enable a full picture to emerge (Mukeredzi 2009). I adopted open-coding which according to Charmaz (2006) is a process involving reading and re-reading data generated in order to compare individual data units and label (code) similar units cluster them into categories then clustering those categories into themes. Open Coding is thus a data analysis approach which focuses on the coding, categorization and conceptualization of phenomena through an intensive analysis of the data (Vollstedt and Rezat 2019). It is therefore an interpretive process by which raw research data are systematically put into chunks, coded, categorised and then clustered into themes before writing up. Figure 3.3 illustrates the data analysis procedure.

Figure 3.3: Data analysis procedure



Source: Researcher (2021)

Once data were generated, several steps were followed to analyse it. This was informed by O'Connor and Gibson's (2003) suggested step-by-step guide for data analysis in qualitative interviews. The analysis followed a six-step approach to data analysis: transcriptions; familiarizing with data; sorting and organizing data; coding and categorizing; developing themes; and interpretation and developing a narrative.

Step 1: Transcriptions. Transcription is the action of providing a written account of spoken words (Stuckey 2014). This process enabled the movement from raw interviews (focus group discussions, individual face-to-face interviews and photo-elicitation) on audio tapes to typed prose. I did the transcriptions myself to immerse myself in and understand my data. Transcribing myself was also vital as it helped me to preserve the accuracy, integrity (Bailey 2008) and confidentiality of my research data. I transcribed immediately after conducting discussions and interviews while the responses were still fresh in my mind and this helped in situations where audios were unclear. Transcriptions were typed verbatim. This was informed by O'Connor and Gibson's (2003) notion that transcripts should be able to "give the best reflection possible of how the conversation actually happened." Transcribing verbatim was also critical to avoid distorting participants messages and risk the loss of credibility for my study. This was a laborious task which took a lot of time and patience to do. Bailey (2008: 1) confirms that transcribing can take "at least 3 hours per hour of talk … up to 10 hours per hour with a fine level of detail." In the next stage I discuss familiarizing with the data.

Step 2: Familiarizing with data: After transcribing data I had to familiarise myself with teacher's stories through reading and re-reading transcripts and sparse notes taken during interviews, and listening to audio-recordings repeatedly. This iteration process helped me to understand the messages conveyed during discussions. This was based on O'Connor and Gibson (2003: 65) who contends that researchers should "start the analysis process by getting to know … data." These were efforts adopted to also promote understanding of the world of my participants for easy interpretation and analysis of the data. I would play these audio recordings in the car while travelling or on a speaker in the house. This idea was informed by Austin and Sutton (2014) who argue that familiarizing with participants stories helps to understand participants experiences of the phenomenon of interest in the study. This activity played a significant role in understanding new ideas without being influenced by my own notions and biases. Familiarizing with data is a strong attribute of qualitative research which Mulholland and Wallace (2003) refer to as 'enhancing legitimation in qualitative inquiry'. This step was followed by sorting and organizing the data.

Step 3: Sorting and organizing. Data were generated to answer research questions. It was therefore imperative to sort and organize the data according to research questions that particular data addressed. Chowdhury (2015:122) defines sorting and organizing qualitative data as, "the placing of similar objects or entities together to facilitate easier analysis and assessment of the data." Sorting and organizing the data required me to understand the data so that I could determine which data addressed which question and sort and organize it accordingly. I used different highlighters (red, green and purple) to identify participants responses to the three different research questions as I sorted the data on transcriptions. This process was guided by Trint's (2019) notion which explains that qualitative researchers can easily get lost in a 'sea of oral responses' if they were not sorted and organized according to their subject. I had to revisit the data over and over again reading it carefully to identify aspects that addressed the same question while I also noted existing differences. As I did this, I guarded myself against the influence of my meanings, perceptions, interpretations and biases while I respected participants views which Creswell (2003) referred to as bracketing. Weatherford and Maitra (2019: 91) define bracketing as, "completely abstaining from any judgement regarding the research process" in mitigating against bias. Organizing and sorting data under each research question enables the researcher to see at a glance the similar patterns and themes (Cohen et al. 2018). During the process I kept focused on my major research question and its subsidiary questions. Notwithstanding that I pooled the data across the participants and sources together during the process of sorting and organising according to the research questions, I kept the data from the different sources separate under each question and marked the data in such a way that I could easily identify data from a particular source and particular participant. Through this process I listened to audio recordings over and over again and read transcriptions several times to have a picture of the world of my participants.

Step 4: Coding and categorising.

Coding: Linneberg and Korsgaard (2019) called coding 'a communicative and trustworthy story' of my participants' responses. This was an operation which involved examining a portion of a participant's response and summarizing the content by attaching a code. A code is, "a word or short phrase that symbolically assign a summative, salient, essence of capturing and/or evocative attribute for a portion of language-based or virtual data" (Saldana 2008: 3). Thus, coding was not just a way of labelling data but linking from the data to an idea which could assist the interpretation. This again, required revisiting transcriptions to verify participants stories and comparing with the sorted and organized data to check whether I had captured all the appropriate codes. Strauss (1987) emphasises the importance of coding arguing that proficiency in qualitative research depends on excellence in coding. This is echoed by Crosley and Jansen (2020) who also argue that good coding promotes high quality analysis. Coding was an iterative process which was done repeatedly to reconfigure the codes and establish patterns. Richards and Morse (2007) conceive coding for patterns in the data as indexing which makes data readily accessible for analysis.

Categorizing. Categorizing was a way of grouping codes together because they had something in common. Creswell (2013: 156) view categorises as "broad units of information that consists of several codes aggregated to form a common idea." The process of categorising was iterative and took a 'loop-like' pattern where the data were revisited multiple times as additional questions emerged and new connections were realised. I thus re-examined each and every code referring back to transcriptions in order to answer the question, 'what is this about?' (Mukeredzi 2009). Drawing from Miles and Huberman (2014), the analysis was guided by questions such as: what patterns and common ideas emerge in responses dealing with specific items? How do these patterns help or not help to illuminate the broader study questions? What interesting stories emerge from the responses and how do these stories answer research questions? These and other questions assisted data analysis and at every stage data reduction was necessary to reconfigure the data by selecting, focusing, simplifying, associating and transforming data from the transcriptions (RWJF, 2011).

Step 5: Developing themes. This stage of data analysis involved streamlining on the basis of their relatedness, the categorises identified in Step 4 above into themes that would answer for example: how FET mathematics teachers professional learning through teaching roles influence their pedagogical practices. This data analysis procedure was based on Saldana's (2016:15) perception that "a theme can be an outcome of coding, categorising or analytical reflection but it is not something that is itself coded." In this context, I used primary data which I had code, categorised to develop themes answering questions such as why, how, in what way or by what means? in answers to my research questions. However, Miles and Huberman (1994) advised that in qualitative analysis words represent individuals so that they are a reality that is difficult to cut out without adequate reasons. It was noted therefore, that the acid test for any generated data was how relevant the data would be in answering prescribed research questions. The different codes of categorized data were then grouped and reconfigured into themes which served as answers to research questions. Thus, themes were broad concepts generated from codes and categories developed in answer to research questions. Even at this stage, I had to go back to the transcriptions to verify the themes and ascertain that they remained representative of participants responses rather than my own ideas. Table 3.2 below shows how I coded data, categorised and developed themes as I analysed data.

Table 3.2: Coding, categorising and developing themes

Data	Codes	Categories	Themes
Interviewer: Tell me the activities that you do as an FET mathematics teacher. **Interviewee:** Being a mathematics teacher requires a lot of work. I have to prepare for my lessons. I also attend workshops. Sometimes you	Doing a lot of work Prepare for my lessons. Attend workshops	Lesson preparation Workshops	Classroom practice Workshops

think you know a lot but when you attend a workshop you realise that you did not know much. **Interviewer:** Is that all you? Please tell me more. **Interviewee:** I also help learners with their questions, mark learners exercise books and share ideas with colleagues in the maths department.	Learning from others Helping learners solve their mathematics problems Marking learners exercise books Sharing ideas with colleagues	Discussions Remedial and extension work Assessment Interaction	Classroom practice

Source: Researcher (2021)

The process of coding and categorising data and eventually developing themes landed me in a hermeneutic circle. McCaffrey et al. (2012:1) define a hermeneutic circle as, "a review and refashioning, a looking back in order to look forward." I had to look back at the transcripts to verify the codes and from the codes proceed to form the categories and from categories back again to the codes and transcripts in order to ensure the categories depict the lifeworld of my participants. This was informed by the ideas of Vieira and de Queiroz (2017: 10) who conceive the hermeneutic circle as an art of interpretation and understanding of a text in a circular movement investigating "a phenomenon and its elements, structures and types as well as its pre-existent context." Vieira and de Queiroz explain that if the first understanding happens, the recurrent movement happens from which new understandings emerge. As I read and re-read the texts, I was guided by the question: what can be interpreted and further understood from this text? Through this inquiry, the hermeneutic circle opened new perspectives about the data as I gained better understanding of the data in participants texts through reading and re-reading the texts.

Step 6: Interpretation and developing a narrative. Interpretation of data was an on-going activity which involved going back and forth reviewing the data for clarity and the identification of existing patterns in it. At this stage, I stopped and examined my data analysis, repositioning the themes in their overall contexts from where they emerged to see whether there were relationships. This helped me to determine whether the analysis could be put together into a narrative that depicted a clear impression of the professional learning of FET Grade 12 mathematics teachers in their roles, what they learnt and how the learning influenced their teaching practice as revealed in the literature. Drawing on Cohen et al.

(2012) who emphasize employing neutral individuals to go through the data set to identify errors or omissions and confirm themes, I sent the complete set to my supervisor at each stage to go through my analysis, checking for errors or oversights, and verifying themes. Subsequent to this, I set out to develop the narrative. Following this, I engaged with data and described and interpreted FET mathematics teachers experiences and actions in their roles which contributed to their professional learning in a narrative. In addressing my research questions through thick descriptions in the narrative, I kept asking what, how, why and when questions to describe the professional learning of FET mathematics teachers in their roles. This notion was founded on Devanga et al.'s (2014) principle that thick descriptions have 'to show rather than tell' in their nature. Subsequently, I scrutinized the codes, categories and themes, examining data and selecting appropriate quotations that depicted themes, enabling appropriate representation of participants. The quotations substantiated participants' stories of their professional learning, the knowledge that they gained and how the learning influenced their pedagogical practice. Singleton and Straits (1999) cited by Mukeredzi (2021:349) view this as, '. . . capturing in their language and letting them speak for themselves'.
The next section discusses issues of trustworthiness in research.

Trustworthiness

Trustworthiness refers to a process of ensuring research remains consistent with the purpose for which it is intended (de Vos et al. 2009: 345). Trustworthiness is basic in research and a prerequisite for the production of credible and dependable research projects. De Vos et.al. therefore, identify the following questions to guide researchers to meet this obligation: How convincing are the real findings of the study? Can the findings of the study be applicable in another setting? How can we be sure that if the same study is repeated among the same participants in the same context, it can achieve similar results? Are the findings reflective of the subjects and the inquiry itself rather than the biases or prejudices of the researcher? This section will unpack this study's trustworthiness through its factors of credibility, transferability, auditability and confirmability.

The first question speaks to the **credibility** of a study (Lincolin and Guba 1985:290). Credibility refers to the confidence earned when research findings reflect the views of research participants (Mills et al. 2010). In this context, research credibility was associated more with the richness of the data rather than the amount of the data generated. This was anchored on Mills et al.'s (2010) idea that credibility is a criterion where the researcher is obliged to link research findings with reality to show the truth about the research findings. Informed by Mills et al’s notion, I employed triangulation (multiple methods: focus group discussion, individual face-to-face interviews and photo-elicitation) for data generation to gain complete understanding of the phenomenon (the professional learning of FET mathematics teachers in their roles). In this study, findings were presented in thick descriptions to describe the phenomenon. The study parameters were also defined to provide the de-limitations of the study in an effort to direct the study towards achieving its specific objectives. Lietz and Zayas (2016: 191) suggest that in qualitative research interpretations must be authentic and accurate to the descriptions of the primary participants. Interpretations have to speak to what the primary source of data indicates and avoid researcher bias and preconceived ideas. To achieve this, researchers must manage the risk of research reactivity and bias (Padgett, 2008). I dealt with this threat by remaining aware of how research procedures might impact on the credibility of the data and mindful of the potential influence of my own bias. I thus bracketed my own preconceived notions and ideas about the phenomenon under investigation. I made concerted efforts to make data generation simple and straight forward and free from deception among participants through clarifying interview questions and probing. I engaged in reflexivity and building self-awareness regarding my personal influence on the project. For example, I had to set aside pre-conceived ideas and stick to what I found from the data. Through triangulation (use of two or more sources in gathering data (Padgett 2008: 186) I was able to achieve credibility of the study as different methods of data generation confirmed data and complemented each other.

The second question relates to the **transferability** of the findings from the study. Transferability encompasses how research findings are considered “applicable or useful to theory, practice and future research” (Lietz and Zayas 2016:192) which is technically coded as “fittingness” (Sandelowski 1986). It is the extent to which findings fit situations outside of the study. To achieve transferability in the study, I employed theoretical frameworks to analyse data and explain findings guided by concepts and models. Transferability was also enhanced by relating findings to existing research as well as providing thick descriptions of the research setting and of the findings which allowed readers to understand ways how the findings of this study weaved into other settings, theory and practice (Creswell and Miller 2000; Shenton 2004). The aspects left the decision to transfer findings to other similar settings to the reader.

The third question explores the **auditability** of the study. Auditability of the study is the extent to which research procedures are documented making it possible for someone outside the project to follow the arguments and be able to critique the research process (Padgett 2008). This was fundamental to the trustworthiness of the research as it demonstrated the path followed to the findings of the study and justified its authenticity. To enhance this dimension of trustworthiness, I kept an audit trail (a written account of the research process throughout the research project) and engaged in peer debriefing (consulting with colleagues doing similar studies and promoting reflexivity) during cohort sessions that were organised by the supervisor at the university campus in Pietermaritzburg. Allison (2005) believes that reflexivity like flexibility enables the study to achieve a better fit within the environment where it is conducted. In this regard, reflexivity promoted the situation where my study would not be detached from the environment in which it was conducted. Peer debriefing and reflexivity also involved checking with other fellow students and/or some participants to determine relevance to the intended study. The fourth question sought to endorse the research project as the result of the experiences and ideas of the participants rather than the subjectivity and preferences of the researcher (Shenton 2004: 72).

Confirmability relates to the extent to which a study can be confirmed or corroborated by others (Connelly 2016; Shenton 2004) who read it. It is a factor in trustworthiness which assesses the degree of neutrality of the researcher's findings. Connelly (2016: 74) conceive confirmability as founded on principles of ensuring that the findings are "a result of participants responses rather than the characteristics and preferences of the researcher." Confirmability was thus, addressed by demonstrating a clear link between the findings and the data obtained from data generation processes so that the project could be viewed as original and unique in its own right. The link was established through constant reference to generated data sources such as the audio recordings when reviewing the findings. The step-by-step procedures in data generation and analysis presented earlier provided triangulation and an audit trail that could form the basis for tracking the path to the findings from the study which was vital for establishing confirmability. Further, I utilised fellow students and my supervisor who were outside this project to read through my chapters and evaluate or confirm the research procedures. This was also enhanced by discussions with peers during cohort sessions organised by the university. Therefore, confirmability served as the qualitative instrument's comparable concern to the study's objectivity.

Ethical issues

Ethics involves a set of rules or guidelines, written or unwritten that direct our expectations and behaviours during research. Cohen et al. (2008) perceive ethical considerations as a cost/benefit ratio of social benefits of the research versus the personal costs of those taking part in the research project. It was the balance between what I intended to benefit from the research project compared to the risks that those who took part in the research tended to expose themselves to. In other words, the set research questions of this study would not be achieved at the expense of participants (the FET mathematics teachers). Resnick (2015) views ethics as serving to promote the aims of a research, support the values required for collaborative work, researchers' accountability and the social and moral values of participants. Ethics is important to avoid infringing into participants' rights in any form (Christensen et al. 2015). Thus, consideration of ethical issues was intended to avoid trespassing my participants' (FET mathematics teachers) rights. This section will discuss natural and procedural concerns that I needed to consider to avoid compromising my study and enhance research credibility and dependability such as: informed consent, problems and dilemmas confronting the researcher among others.

Informed consent involves giving participants the right to choose to be part of the research process or not without coercion. Nijhawan et al. (2013) explain it as the process where potential research participants are told about key aspects of the study and what their participation would entail. While informed consent is perceived as a major aspect of ethics in research, Xu et al. (2020) argue that there are challenges associated with it regarding what must be disclosed and methods of obtaining consent. In this study, the researcher got a chance at a subject meeting to explain procedures to be followed in the research process, expected duration of the study, issues of confidentiality and right to participation. A chance for participants to ask questions regarding the project was provided. During data generation, participants were reimbursed for transport costs and drinks and snacks were served during sessions. Participants were informed that they would be involved voluntarily and were able to withdraw from participation if they found themselves uncomfortable in the study. They were allowed to suggest other ideas they found useful and suitable to them such as time, duration of interviews and venues.

Problems and dilemmas confronting the researcher are imminent at all stages of a study from inception to the end. These include such issues as privacy, anonymity, confidentiality and betrayal (Cohen, Manion & Morrison, 2008). Among these problems and dilemmas, is the potential impact of the researcher on his/her participants (Colnerud 2014) which must always be guarded against to avoid the researcher's undue influence on participants. I discuss the issues of concern raised above in the order they are presented starting with privacy.

Privacy: Protecting research participants' right to privacy involves respecting their autonomy, right to self-determination and their general welfare. NEEP (2012) conceive privacy in qualitative research as a function of acceptable social norms and individual expectations regarding what participants choose to declare and/or not declare in public. I respected my participants autonomy and self-determination and would not infringe the right to privacy of the participants' information. I avoided at all costs discussing information obtained from my participants with friends except with my supervisor. Participants were also free to withhold sensitive information (personal or potentially threatening information) to the research process.

Anonymity: Anonymity refers to participants not exposing their identities during data generation sessions. This is confirmed by Saunders (2015: 1) who perceive anonymity as "keeping participants identities secret." In this regard, anonymity suggests that a participant in qualitative research should never be traceable from the data that is presented about them. I used coded names for individual participants in data generation and in the research write-up. I also assured participants that their identities were protected throughout the research process. I kept the audio records from interviews, and focus group discussions in password protected files so that the voices were only accessible to me and my supervisors.

Confidentiality: Confidentiality is a promise to protect a participant's right to privacy and anonymity (Cooper and Schindler 2001:117). While anonymity could be viewed as a form of confidentiality, unlike the definition of anonymity above, confidentiality in this study was conceived as keeping the data generated in secret. I secured obtained data from participants in a safe room which was always kept under lock and key.

Betrayal applies to occasions where data disclosed in confidence finds its way in the public causing embarrassment and in some cases suffering. It is a breach of trust among trustees. In this study, where information was given in confidence, confidentiality was maintained by keeping what was shared in confidence a secret between myself, participants and my supervisor. The next section discusses the limitations of the study.

Limitations of the study

It is hard and/or impossible to conduct research free of limitations. Limitations of the study are defined by Price and Judy (2004) as characteristics of research design and methodology which may influence the interpretation of data and research findings. This section therefore discusses two major limitations that may have affected my study findings.

To begin with, the philosophical orientation, design and approach of the study, inclusive of the sampling designs, and data generation methods gave rise to lack of generalisability of the findings. It is generally understandable and acceptable when using qualitative approaches that generalisability is not the main aim of such studies. Padgett (2008: 182) indicates that constructivists challenge the relevance of generalisability in qualitative research, "arguing that an emphasis on generalising strips away the context that imbues a qualitative study with credibility". However, transferability of this study's findings could be considered on the understanding that the findings could only be limited to similar specific groups of participants or circumstances (Creswell 2013). It will therefore be up to the reader to assess the findings and decide whether or not to transfer these findings to another setting, based on their understanding and experiences, the thick descriptions of the research sites and the data presented in this thesis.

Lastly, I was a mathematics teacher in CHE District known to participants although not at a personal level. This connection with the participants could have given rise to my attitudes and opinions, as well as tendencies to view participants in own image or even to look for answers endorsing my own notions and philosophies which may have affected the findings. Further, researcher slip-ups on given answers or misapprehensions of participants' responses may impact on research findings (Soltis, 1989). I made a concerted effort to bracket my own notions and pre-conceived ideas and remain open-minded, listening carefully and following up on questions during interviews and listened to audio records over and over. All this was to get accurate information and clarifications. Further, I declared my own axiological assumptions and experiences in Chapter one.

CONCLUSION

This research methodology chapter started by discussing paradigms and their assumptions: epistemology, ontology, axiology and methodology. Given the paradigmatic orientation of this study, epistemologically, there was a close researcher-participant relationship, no distance between the researcher and the researched as data were socially co-constructed. With regard to ontological assumptions, the data generated were subjective and appropriate ethical principles of dealing with research participants and conducting research were upheld throughout this study. The methodological assumptions which dealt with the practical aspects of the research process enabled choices of design, approach, and methods of data generation. The chapter also discussed the interpretive paradigm which, due to its subjective orientation and understanding phenomena from the perspective of participants' lived experiences, was relevant for the study. The methodology of the study where case study design, qualitative approach involving non-random sampling designs and data generation through focus group discussion, face to face interviews complemented by photo elicitation were also discussed. How data were analyzed as well as some perceived limitations of the study, and how these were addressed to minimize their impact on findings were also dealt with to conclude the chapter.

Having discussed the design and methodology in this chapter, the next chapter focuses on data presentation and analysis addressing research Question one about how FET mathematics teachers engaged in professional learning through teaching roles.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS: HOW FET GRADE 12 MATHEMATICS TEACHERS ENGAGE IN PROFESSIONAL LEARNING THROUGH TEACHING ROLES

Introduction

The study revolved around how FET Grade 12 mathematics teachers professionally learn through their teaching roles, the types of knowledge they gain and how the learning influences their practice. The preceding chapter discussed the methodology adopted for the study. Located in the interpretive paradigm, case study design and qualitative approach, data to address the stated aims were generated through focus group discussions (FGDs), individual face-to-face interviews (FF Interviews) and photo-elicitation interviews (PEIs). As detailed in the methodology chapter, the photographs that participants took were only used to prompt discussion: as such they are not displayed in this thesis to ensure participant anonymity and confidentiality.

The main research question that this study addressed was 'How do FET Grade 12 mathematics teachers professionally learn through their teaching roles and how does the learning influence their practice'. This main question was addressed through the following sub-questions:

1. How do FET Grade 12 mathematics teachers engage in professional learning through teaching roles?
2. What kinds of professional knowledge do these teachers gain?
3. In what ways do these teachers say their professional learning influences their practice?

In this study, findings addressing each research question constitute a chapter. This chapter presents and analyses research findings addressing Research Question One on how FET Grade 12 mathematics teachers engage in professional learning through their teaching roles. In presenting and discussing findings I integrated data from all instruments and all participants as responses were generally similar.

The data are presented and analysed drawing on literature discussed in Chapter Two to illustrate how my findings support or contradict existing research. The findings are analysed and explained drawing on the Triple lens theoretical framework (Fraser et al. 2007) and the

Mathematical knowledge for teaching (MKT) theoretical framework (Ball et al. 2008) around teacher professional learning, also outlined in Chapter Two to show how findings can be understood from a theoretical lens. The triple lens theoretical framework includes Reid's spheres of action, Bell and Gilbert's domains of influence and Kennedy's models of continuing professional learning: A framework for analysis (Fraser et al. 2007). This theoretical framework is drawn to analyse and explain data addressing Question One.

The specific question addressed in this chapter is: *'How do FET Grade 12 mathematics teachers engage in professional learning through teaching roles?'*. What generally emerges is that FET Grade 12 mathematics teachers in their teaching roles experience professional learning in two learning sites: in-school and out-of-school through practice, non-formally and informally. These findings are discussed according to these sites: professional learning within the school and professional learning in wider professional sites.

Themes and Sub-themes

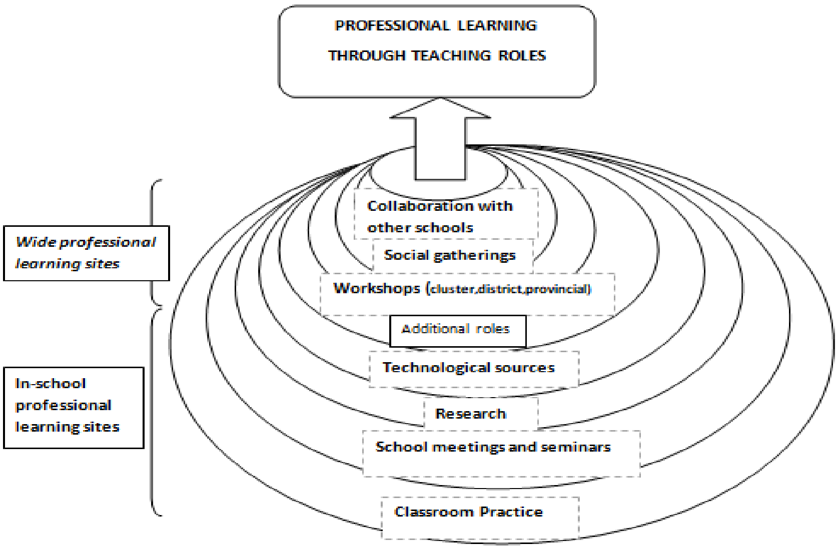
Eight themes emerged in answer to this question: classroom practice; school meetings and seminars; research; technological resources; and additional roles. These provided professional learning spaces within the school site. Professional learning through workshops, social gatherings and collaboration with other schools offered learning in wider professional sites.

The professional learning sites and their respective themes are represented in Figure 4.1.

In Figure 4.1, the bigger the area reflected the greater the professional learning that FET Grade 12 mathematics teachers reported. Thus, the diagram was thought of as a building where the foundation plays the very vital role of sustaining that building. The foundation has to be wide and strong as the life of the building depends on it. In this study, classroom practice as the major theme is the foundation upon which professional learning through teaching roles is built.

The chapter begins by analysing data and presenting findings around professional learning within the school site. This will be followed by a discussion of how the FET Grade 12 mathematics teachers professionally learnt through wider professional sites. In each section related themes are discussed and summarised through their subthemes. The key points from each site are then tied together in the conclusion.

Figure 4.1*: Ways the FET mathematics teachers engaged in professional learning through teaching roles*.



Source: Researcher (2021)

To ensure confidentiality and anonymity in reporting and discussing findings, participants are identified using codes, for example, Teacher 1 to Teacher 26. In addition, data generation techniques are represented as:

Focus Group Discussions: FGD 1-4;

Photo-Elicitation Interviews: PEI.

Individual face-to-face interviews: FF Interview.

Table 4.1 shows the number of participants who reported professional learning related to the different spaces – themes discussed in this narrative. For example, while all 26 FET Grade 12 mathematics teachers reported having experienced professional learning through classroom practice, 18 reported professional learning through school meetings and seminars, while 12 reported professional learning through research.

Table 4.1: *Representation of participants' indications of professional learning in different learning spaces*

THEMES	Classroom practice	School meetings and seminars	Research	Technological resources	Additional roles	Workshops	Social Gatherings	Collaboration with other schools
TOTALS	26	18	12	23	20	26	14	8

Source: Researcher (2021)

The following section discusses professional learning within the school site.

PROFESSIONAL LEARNING WITHIN THE SCHOOL SITE

In-school activities through which FET Grade 12 mathematics teachers reported professional learning are those activities that the teachers engaged in within the school. Classroom practice, school meetings and seminars, research, technological sources and additional roles emerged as major themes within which professional learning was realised in the school site. This section, which discusses professional learning within the school site, begins by discussing teacher professional learning through classroom practice and its related sub-themes.

Classroom practice

Classroom practice in this study involves all the teacher and learner activities carried out both in and outside the classroom from which both teachers and learners benefit. These are planned and formal activities which define teacher teaching roles and distinguish teachers from other professionals (Kuriachan 2018; Mitchell and Lumb 2009). Formal and planned activities are in tandem with Reid's spheres of action (Fraser et al. 2007). The 26 FET Grade 12 mathematics teachers reported that they engaged in professional learning through their classroom practices. This finding links well with Villegas-Reimers's (2003) precepts that professional learning for teachers occurs in actual classroom teaching experiences and daily activities of teachers and learners. From literature surveyed (Kelly 2006) classroom practice learning experiences represent learning-in-practice which is tacit, distributed or stretched, across people and their settings. This theme is discussed under lesson preparation, lesson delivery, assessment and feedback, classroom management and team teaching. These sub-themes are discussed in turn below.

Lesson preparation

Professional learning through lesson preparation in classroom practice in the school site, was reported by all the FET Grade 12 mathematics teachers. Lesson preparation usually refers to gathering all necessary materials and equipment for a pending lesson in advance to facilitate effective lesson delivery. Literature consulted indicates that lesson preparation involves going through thinking processes to determine what is needed and how it could be used to effectively drive home the intended concepts (Lim et al. 2019). Lesson preparation is, therefore, perceived as deciding what to teach, how to teach, when to teach, thinking about ways to expand it and take note of what else is needed to be done before going to class (Lim et al. 2019; Sudhakar 2017). This teaching role, thus, requires careful thinking to provide logical sequencing for the arrangement of a lesson. Hence, this preparation encompasses lesson planning and the preceding activities of determining and sourcing materials and equipment necessary for an effective lesson. Lesson planning is also viewed as the art of putting on paper a teacher's detailed description of the course of instruction to guide class learning (Mulheron 2019). Thus, preparation is viewed as the first step in the process of planning the lesson. In explaining how they professionally learnt from lesson preparation, one participant, Teacher 5 in FF Interview 1, said:

> *As a Maths teacher I learn as I prepare for my lessons. This is not an easy process because it involves many things such as reading text books, talking to colleagues and working out some maths problems.*

Another participant, Teacher 6, during FGD 2 echoing similar sentiments said:

> *One of my key duties is to prepare for my lessons. I always spend time learning by practising mathematics exercises in readiness for my lessons. I need to consider the ability of my learners to prepare for my lessons.*

According to the participants above, FET Grade 12 mathematics teachers experienced professional learning through classroom practice with regard to lesson preparation from reading books, consulting colleagues, aligning the lesson with learner capabilities and practising the mathematics problems that they would teach in the subsequent lesson. From all these processes and activities, the teacher is likely to have adequately prepared for the lesson and goes into it fully armed for effective delivery. Literature surveyed (TESSA 2009) emphasises extensive reading and collegial consultations as effective sources of professional learning. Collaboration and consultations referred to are vital for sharing expertise and ideas as noted by Mukeredzi (2009). Extensive reading and consulting colleagues are consistent with Mathematical knowledge for teaching's (Ball et al. 2008) specialised content knowledge domain which proposes that teachers must have extensive knowledge of their content and of strategies of teaching. The teachers also explained that lesson preparation required consideration of the ability of their learners so that all learners are catered for during lesson delivery. Knowledge of learners and their characteristics (Shulman 1987: 8) is paramount for ensuring relevant and appropriate choices of content knowledge levels during lesson preparation. Broderick (2017) and Cumberland (2019) both confirm that lesson preparation must cater for different levels of learner cognitions. Hence, lesson preparation enables teachers to professionally learn from selecting materials and preparing lessons for handling learner learning diversity. Practising mathematics problems provided opportunities for these teachers to rehearse their lessons and identify critical mathematical knowledge for teaching which is consistent with the triple lens occupational domain of influence (Fraser et al. 2007). This enabled identification of grey areas and concepts for emphasis in the lesson. Professional learning in classroom practice through collegial discussions was also raised during FF Interviews:

> *Preparing for my lessons involves knowing how others teach certain topics and also reflecting on lessons that I have taught through responses of learners that I have taught over the past years on how they answered certain questions. I also talk to learners to hear their views on how I teach mathematics so that I can teach better.* (Teacher 7 in FF Interview 1)

Usually consulting colleagues, reflecting on previous lessons and considering learner responses by teachers in their roles ensure thorough lesson preparation. These activities promote self-evaluation, critical thinking and enhance careful consideration of materials and methods for inclusion in preparing a lesson. Reflection on previous lessons engages teachers in analysis and examination of their practice which promotes professional learning through teaching roles. Through these informal dimensions of teacher professional learning, according to Reid's quadrants (Fraser et al. 2007), Teacher 3 in a PEI supported the view saying: *"I involve my learners and my colleagues in preparing for my lessons. I learn from others what I can do to come up with a successful lesson."* Teacher 7 during FF Interview 1 and Teacher 3 during a PEI above concurred that FET Grade 12 mathematics teachers engaged in several activities during lesson preparation and, consequently, experienced professional learning in the process. The responses also indicated that FET Grade 12 mathematics teachers engaged in professional learning around classroom practice through reflection on previous lessons and reflection on learner feedback which is noted by Mukeredzi (2015) in the literature. Reflection enables professional learning by answering the question 'What should I have done differently?'.

Reviewed literature (Kazima et al. 2008) asserts that talking to learners, as noted by Teacher 7 above, promotes teacher professional learning as the teacher can use learner feedback and students' assessment results to judge the effectiveness of their materials and methods and see how they can improve. These teachers collaborated and reflected through discussions on performance in examinations to improve their teaching and learning practice (Woods 2014). They consulted peers and shared apt approaches and teaching strategies (Fraser et al. 2007) for effective lesson preparation and, consequently, delivery. Thus, the teachers professionally learnt through collaboration and reflection in their teaching roles (Mukeredzi 2013). A participant, Teacher 3 in FF Interview 1, further elaborated how they professionally learnt saying: *"My other responsibility is to reflect on my lessons through learner responses during oral questions and written exercises in order to inform my lesson preparation."* Reflection on lessons taught and on learner performance in answering oral questions and in written activities offered these teachers another avenue for professional learning, as new lessons could then be improved. Consulted literature (Mukeredzi 2013) explains that reflection and review of learner responses to oral questions and written activities set teachers to think and learn from their errors and situations in their teaching. These activities helped the FET teachers to understand what they could have done differently, thereby subsequently preparing for better lessons. The teachers also drew on learner opinions (McLeish and Snowden 2017) regarding their teaching so that their expectations could be accommodated in lesson preparation. Thus, FET Grade 12 mathematics teachers professionally learnt in lesson preparation as they thought through their lessons, reflected on previous ones and consulted learners and colleagues.

Other participants in focus group discussions mentioned professional learning around teaching strategies from watching TV mathematics teaching channels and this enhanced lesson preparation. My theoretical framework (Fraser et al. 2007) acknowledges the importance of learning in the occupational domain, such as knowing teaching strategies when preparing for effective lessons. Teaching strategies are pedagogical approaches necessary for teachers to create and facilitate effective teaching and learning (Francis 2018). Shulman

(2009) perceives pedagogical knowledge as special knowledge teachers need in their teaching roles to enhance their strategies of teaching, classroom management and organisation that appears to transcend subject matter. Usually, demonstration lessons screened on national television are well presented lessons meant to benefit learners and teachers. Thus, Teacher 5 during FGD 4 made reference to learning teaching strategies from TV mathematics teaching channels and said:

> *I learn a lot of teaching strategies from TV teaching channels such as Channel 911. The channel shows how different topics can be taught to learners. Now I am exposed to many teaching strategies for teaching many topics.*

Another participant during a photo-elicitation interview also reported that:

> *Here (showing a photograph) I was watching a TV programme on teaching functions. I learnt many teaching strategies for teaching functions from different teachers who presented lessons on different functions.* (Teacher 8 during a PEI)

Functions are a topic in the FET Grade 12 mathematics syllabus which is often difficult for teachers to teach. The FET Grade 12 mathematics teachers observed model lessons on TV regularly as they prepared for their lessons daily. Through these demonstrations, teachers were mentored (Fraser et al. 2007) in their practices. Observing lessons on TV brought new dimensions of thought in preparing lessons for these teachers. Again, lessons on TV widened their scope of teaching strategies in their teaching roles. Literature surveyed (Schmidt et al. 2009) acknowledges that observing demonstration lessons improves teachers' teaching strategies. This was consistent with the general principles of pedagogical knowledge which enshrine the principles and strategies of classroom management and organisation (Shulman 1987: 8) for effective instruction.

Further, lesson preparation requires knowing the relevant syllabi in the subject to avoid short changing learners in their learning as explained by a participant, Teacher 13, during a PEI, below:

> *I am motivated to learn from my syllabus to prepare well in my subject and make sure everything is covered to avoid short changing my learners …. So, I have to read my CAPS document and exam guidelines to prepare lessons properly.*

The participant above made it clear that lesson preparation must cover relevant content of the syllabus. Literature consulted (TechAnology 2019) points out that teachers must prepare adequately to cover syllabi in their lessons. With regard to this, teachers needed to prepare for lessons using the CAPS document and examination guidelines in order to cover all topics as outlined in these documents (DBE 2018). Generally, the CAPS document is a policy instrument guiding teachers at all levels about what must be taught to learners in given grades. The examination guidelines are documents that are often released by chief markers highlighting common errors that learners made in previous examinations on different topics. Consistent with Reid's theory (Fraser et al. 2007) the teachers closely referred to these formal curricular policy documents. They considered relevant concepts for teaching different ability levels of learners during lesson preparation. Thus, lesson preparation requires thoroughness and accuracy if it has to adequately inform lesson delivery. Consequently, the amalgamation of teaching content and curriculum policy was a professional learning curve for these teachers. Hence, consulting the CAPS document and examination guidelines created space for their professional learning in their teaching roles.

Teacher 8 during a PEI discussing a photograph had this to say:

> *Here (showing a photograph) I was preparing for a lesson. I learnt that it is good to prepare for lessons before you go for teaching. This is so because I do not struggle to find my feet in the lesson after lesson preparation. All the information and strategies will be on the finger-tips.*

Teacher 8 foregrounded the importance of preparing for lessons beforehand to inform lesson delivery. Preparing for lessons beforehand is consistent with the theoretical framework (Fraser et al. 2007) which upholds standards in lesson preparation and delivery. Advance lesson preparation was critical for these FET Grade 12 mathematics teachers to familiarise themselves with their teaching materials. The activity helped them to rehearse their lessons and have knowledge at their fingertips which developed their confidence during instruction. Thus, these participants confirmed learning through this lesson preparation process.

All the 26 explored FET mathematics teachers also reported professional learning around lesson preparation through joint planning. The joint planning was done with colleagues from other schools. This is exemplified by Teacher 9 during FGD 2 who said: *"I learnt from others as we prepared for our lessons together. It enhanced our performance as a department in the school."* Another participant, Teacher 4, during a PEI supported the idea saying: *"Here, (showing photo) I was with my two other colleagues discussing and preparing for our new topics. I always learn from these discussions with colleagues."* In their teaching roles, FET Grade 12 mathematics teachers professionally learnt from each other during team lesson preparations. Teamwork in lesson preparation enabled professional learning for these teachers and improved creativity in lesson delivery. Again, Mukeredzi (2017) noted that joint teacher work offers space for professional learning as colleagues take note of what others consider as important. Consequently, these teachers experienced professional learning in their teaching roles from preparing for lessons together in departmental planning meetings. This confirms Reid's theoretical framework (Fraser et al. 2007) which points to formal teacher activities as spheres of teacher professional learning.

From the above discussion, lesson preparation emerged as a profound activity for teacher professional learning in their teaching roles. Teachers reported that through classroom practice in relation to lesson preparation, they experienced professional learning through reading text books and official documents, collegial consultations and discussions, working out mathematical problems, considering the ability of learners, choosing teaching strategies, reflecting on previous lessons, self-evaluation, lesson planning, watching TV demonstration lessons, planning together and listening to learners' suggestions. The following section discusses FET mathematics teachers' professional learning in classroom practice through lesson delivery.

Lesson delivery

FET Grade 12 mathematics teachers reported that they experienced professional learning through lesson delivery in classroom practice. Lesson delivery is the teaching role where teachers facilitate learning in and outside the classroom (Bingham and Molina 2011). It is generally a teacher's responsibility where both the teacher and learners are active participants in the process. From the literature consulted, (Rubio 2009; Aburizaizah 2014) lesson delivery involves giving instructions focusing on set lesson objectives while engaging learners in expected activities and pacing the lesson in response to learner needs. Again, literature consulted indicates that lesson delivery is the core business of teachers (Home Career Advice 2018). In this regard, Cox (2009) notes that teacher professional learning occurs at every stage and activity of lesson delivery. The FET Grade 12 mathematics teachers reported that they experienced professional learning from various aspects of lesson delivery. This is exemplified by one teacher during FF Interview 1 who said:

> *During teaching my learning begins when I enter the classroom. I try to understand my learners by inspecting them. I greet the learners, check for absentees, motivate*

them and then introduce my lesson and continue to monitor the lesson throughout (Teacher 5 FFI interview 1).

According to Teacher 5 above, some of these FET teachers in their teaching roles experienced learning in lesson delivery by observing, checking, motivating and monitoring their learners during the formal lesson (Fraser et al. 2007). Some teachers greeted learners to make them feel warm and welcome and, in the process, developed their learners' sense of belonging. The teachers took responsibility to account for all learners by checking for absences. Hence, the teachers professionally learnt about their attitudes, readiness to learn and attendance. Thus, lesson delivery involves a series of activities that teachers should follow to facilitate student learning (Cox 2013; Home Career Advice 2018) which include setting the scene for the lesson and monitoring lesson progress as reported in the quotation above. The participant reported that as soon as they got into the classroom they prepared learners and set the platform for a successful lesson which created a conducive classroom learning environment. Raccoon Gang (2019) describes the classroom learning environment as space specifically engineered to support thinking and learning for both the teacher and learners. Thus, consulted literature (Perks 2012; Fraser 2003) concur that during lesson delivery teacher professional learning begins by teachers creating a conducive classroom learning environment for learning to take place. The theoretical framework (Fraser et al. 2007) reiterates that the learning environment is a second teacher for any learner and for teachers, hence, the learning for FET Grade 12 mathematics teachers. Fraser et al. further argue that there is a strong association between the classroom learning environment and learners learning outcomes.

Some of these teachers added that they professionally learnt from the different stages of lesson development. Teacher 4 during FGD 1 explaining this said:

> *As I do my lesson, I use different methods and strategies. If during the lesson my methods and strategies do not work, I change them immediately. I learn this by evaluating every stage of the lesson.*

Teacher 3 during a PEI in agreement with this idea, added:

> *Here (showing photo) I was presenting a lesson. Each time I would communicate with my learners to ensure that they are on course with me. If I see that they are lost, then I switch on to some other strategy.*

Teacher 4 above made reference to professional learning in classroom practice through lesson delivery in reflection. What Teacher 4 and Teacher 3 imply here is reflection-in-practice. Consulted literature (Finlay 2008) shows that reflection-in-practice is a way of reviewing one's own actions and experiences with deliberate intentions to continuously learn from them during the experience. This is a personal current encounter (Fraser et al. 2007) which differs from reflection on practice referred to above, which occurs after the experience (action). I would want to understand reflection-in-practice as a monitoring tool for judging how well the instructional process is meeting the targeted intentions. Further, reviewed literature, (Mukeredzi 2015) stresses that reflection-in-practice is a tool that places into focus teachers' experiences and complexities to effectively connect knowledge, practice and learning. From the two participants above, FET Grade 12 mathematics teachers professionally learnt during lesson delivery through reflection-in-practice to ensure that their teaching methods and strategies worked throughout the lesson. In other words, reflection and learning occurred during the action of teaching in relation to set objectives and learner responses.

Other FET teachers also reported professional learning in their teaching roles through on-going written activities which they gave their learners. Teacher 3 in FF Interview 1explained:

> *I teach the learners. I give my learners written exercises to check their progress. I engage my learners in question and answer sessions to find out their attention and whether we are proceeding well together.*

Teacher 1during FGD 2 said:

> *I expose learners to real problem solving and help learners to explain new vocabulary. I also observe the learners to check their understanding of lessons. I think about their work and sometimes discover new methods. So, in short, I learn from the work of my learners.*

The FET mathematics teachers professionally learnt from checking written activities that they gave learners during lesson delivery. All participants indicated that from learners' activities they learnt about their learners' thought processes, understanding and progress. Some (19) FET Grade 12 mathematics teachers commented that they learnt from their learners when they allowed learners an opportunity to demonstrate what they had learnt or were learning in the lesson. Teacher 1 alluded to thinking about or reflection on the experience as a source of teacher professional learning through replaying what transpired. For these teachers, learning occurred when they established what could have been done differently to achieve the best results of their work in subsequent lessons. Teacher 3 in FF Interview 1 said:

> *I give the learners the chance to show if they understood what I taught them. I give them two or more problems to do in class before the period ends. I then learn from their demonstrations as I compare what they have done with the examples given before I can give them some individual work.*

Some FET mathematics teachers (17) also experienced professional learning when learners coached/demonstrated to peers (Fraser et al. 2007) in the classroom. Through this activity, teachers realised the conceptions and misconceptions their learners held about what they were taught. Dennihy (2016) defines such demonstration of learning as presentations learners do in front of peers and teachers usually to determine the standard to which what was learnt was achieved. These teachers also engaged in exercises where they provoked critical analytical thought in their learners. Teacher 13 during FF Interview 1 elaborated on this saying: *"Sometimes I just write problems on the chalk board for brain storming and ask learners to do the problems. Like quiz. From this I learn their mathematical thinking about what they were taught."* Brainstorming is another activity from which the FET Grade 12 mathematics teachers professionally learnt in lesson delivery as part of their roles. Brainstorming is a strategy that enables teachers to gain maximum learner participation in discussions on a topic (Pumb and Kesley 2019). For these teachers brainstorming happened when teachers posed questions to interrogate learners with the view of determining the extent of knowledge their learners possessed about a concept or topic. Teacher 13 explained that the brainstorming exercise set learners into active reasoning mode for solving problems. Such solutions would display what and how learners thought about the concepts at play in that lesson. This is consistent with the theoretical framework (Fraser et al. 2007) where learning was transitional as teachers began to know about the mathematical conceptions and misconceptions of their learners through diagnosis of learner thinking.

Further, 21 FET Grade 12 mathematics teachers also reported professional learning through comments which they made about learners' work, to acknowledge any good behaviour and performance. This was articulated by Teacher 4 in FF Interview 1 who said:

> *I try to inspire learners to learn. I make favourable comments for any good behaviour and good performance. Sometimes I give some tokens of appreciation. Here I learn that motivation influences learner behaviour.*

These sentiments were supported by Teacher 8 during a PEI, who said: *"In this photograph I* *was making a comment about the good work that this learner had written. I learnt that my learners work better when they get good comments from their teacher."* These FET Grade 12 mathematics teachers professionally learnt through motivating learners. The teachers reported that they realised that motivation (domain if influence) (Fraser et al. 2007) fostered learner performance and good behaviour. Consulted literature (Daskalovska 2012) indicates that motivation is controlled by needs and goals where needs initiate learners' and teachers' behaviour and action while goals satisfy the needs. Thus, motivation originates from two fronts: intrinsic and extrinsic motivation (Cherry 2018). Intrinsic motivation is the type of motivation that comes from within the individual and teachers cannot easily influence it. Extrinsic motivation originates from without the individual and it is usually manipulated by teachers in their learners. This is the type of motivation experienced by learners referred to by Teachers 4 and 8 above. This confirms Bell and Gilbert's (2005) personal domain of professional learning influence. Rewards and reinforcement involve the use of tokens and praises as stimuli for learners to learn more (Guyana 2018). The participants explained that giving favourable comments and tokens for the good work their learners had done changed learners' learning behaviour. Surveyed literature (Denny et al. 2019; Cherry 2018) shows that rewarding learners for good learning behaviour motivates learners to do more of similar behaviour. Thus, these teachers learnt professionally from motivating learners.

The use of games in lesson delivery emerged as another activity through which FET Grade 12 mathematics teachers experienced professional learning. For example, Teacher 7 during FGD 3 said: *"Teaching is my major responsibility. I sometimes play games in class for mental development. I do these games because they bring life in my lessons and they help me to learn from fun."* From the comment, Teacher 7 in FGD 3 suggests that using games in lessons promoted learner engagement at cognitive, affective and operative levels (Attard et al. 2019). Again, other researchers (Rutherford 2015; Rowe 2016; Skotinos 2015) encourage the use of games by mathematics teachers saying they stimulate exploration of the number system, strategic mathematical thinking and learner interaction. These teachers mentioned that such benefits from games built fluency and promoted understanding of mathematical concepts among learners. The choice of games in lesson delivery is guided by the personal and social domains of professional learning (Fraser et al. 2007). Thus, teacher professional learning was fostered through mathematical games included in lesson delivery.

The above reports from the FET Grade 12 mathematics teachers related to lesson delivery indicated that this activity offered a wide range of professional learning opportunities for them. They learnt through: setting the scene for a lesson, lesson presentation, observing and monitoring learners during the lesson, using different teaching strategies, interacting with learners, brainstorming and using games during lesson delivery. Their professional learning revolved around what and how they should teach, reflection in and on practice and motivating learners. This was consistent with Bell and Gilbert's (2005) domains of influence where these teachers engaged in professional learning motivated by their desire for personal growth, to relate well to their learners and the intention to excel in their work. The next section discusses findings how FET mathematics teachers experienced professional learning through assessment and feedback.

Assessment and feedback

Another space of the FET Grade 12 mathematics teachers' professional learning that 19 of 26 teachers reported was assessment and feedback. Assessment and feedback are interrelated activities which involve using oral and written tests, assignments, investigations and examinations for purposes of teaching and determining learner progress. Assessment becomes a teaching tool when learners are given informative feedback on marked scripts or tasks to inform them about their performance. Feedback is often realised as a double purpose activity where both teachers and learners report back about their learning. This is where learners feed back to their teachers through written exercises and representative reporting of group work or answering oral questions. Teachers also feedback to their learners through marked work and comments about learners' work. Detailed, informative teaching feedback highlights what learners did wrong, what they did right and how they should proceed. This is professional learning based on transformative nature (Fraser et al. 2007). Literature sourced indicates that feedback becomes valuable when given within a short turnaround time while learners still remember the assessment task (Mukeredzi 2009). Thus, feedback was a source of professional learning for these FET Grade 12 mathematics teachers.

For example, Teacher 10 during FF Interview1 explained that:

> *I learn from testing learners on the work that they have learnt. After teaching I want to know what these learners have gained and to what extent. So, I have to give a test for every topic covered, mark the test and give back the scripts.*

This idea was supported by Teacher 5 in FGD 1 who said:

> *Usually after every topic taught, I give a test and mark to check the progress of my*

learners. I even revise the tests with them to ensure they now know what they did not do right in the first place.

In the quotation above teachers experienced professional learning through assessment and feedback on learner written tests on topics covered. A teacher organisation, ARCP (2012) refers to assessment and feedback as a kind of dialogue that a teacher and learner engage in to influence each other's actions. Thus, assessment and feedback are a two-way communication process from which the teacher and the learner learn. The participants above indicated that during marking teachers professionally learnt from the performance of their learners after marking. Again, when they gave back the scripts, these teachers professionally learnt from the attitude of the learners as they received their marked scripts. Wabisabi (2017) and Breakstone et al. (2016) advise that teachers must be cautious during assessment and feedback as feedback can make or break the will to generate lifelong learning skills. Fraser et al.'s (2007) triple lens theory advises that professional learning can only be sustained by three domains of influence (personal, social and occupational). Mukeredzi (2017) notes learner assessment and critical reflection as areas that enable professional learning. Because the goal of education is to enable students to construct their own meaning of specific content, the teacher provides learning activities that promote the meaning making. Such success can only be measured through assessment. The teacher marks the written work, making running comments indicating where errors or weaknesses occur, and rates the performance of students. The running comments and feedback add to the knowledge of learners on a specific topic or concept covered (Mukeredzi 2017). Consequently, the process and experience of learner assessment leads to teacher professional learning.

The FET Grade 12 mathematics teachers (32) also expressed that teachers should give back marked work timeously. Teacher 3 during PEIs in explanation of this said:

I learn from marking learners' work. Marking must be done timeously so that marked scripts are given back to learners as quick as possible. This is important so that learners get their feedback while they still expect it.

The FET Grade 12 mathematics teachers experienced professional learning through their teaching roles as they marked learners' work and gave immediate feedback. These sentiments were also articulated in FGDs and FF Interviews. Further, the participants explained that delays in giving feedback made learners lose the enthusiasm and motivation to want to know what they failed. Thus, these teachers learnt that feedback can motivate or demotivate their learners. Consulted literature (Wabisabi 2017) noted that assessment and feedback enabled and inspired learners to excel. Assessment and feedback make learners feel good about their learning situations and stimulate the energy to want to improve or uphold their performance (Care et al. 2018; Lorna 2019). Thus, in their teaching roles, FET Grade 12 mathematics teachers professionally learnt through marking learners' work and giving feedback in the shortest possible time. Another important issue raised relates to timeous marking. Any form of assessment is often used as the basis for determining what has to be done next. Watanabe (2017) and Clark et al. (2015) perceive assessment and timely feedback as tools for teachers to investigate learners' learning and to establish confusions, preconceptions or gaps about their learning. Therefore, any delay in feedback becomes stale information which may not be well connected to what was learnt then and as such may not assist ameliorating the learning confusions, preconceptions or gaps. In this regard, assessment emerges as an investigation process of learners' learning by teachers which leads to professional learning and informs their teaching. Thus, FET Grade 12 mathematics teachers reported giving immediate feedback so that their learners get direction, motivation and commitment to learn new work.

The comments made by some participants (17) in this study also indicated that assessment and feedback were teaching activities that provoked emotional instructional and learning behaviour in both teachers and learners. Teacher 3 in FGD 4 articulated this saying:

> *When my learners fail a task, I become angry and sometimes shout at them. Sometimes, I just become worried as to what I should do especially when I see some of the learners cry for failing. But that in most cases helps me to learn about my approaches. I also learn about the feelings of my learners about their learning.*

Teacher 4 during FF Interview 1 supported the idea by adding that:

> *I like marking my learners' tasks but when it comes to feedback it's something else. I find myself frustrated when learners fail. However, it helps me to make a self-inspection about my strategies of teaching*.

The FET mathematics teachers concurred that assessment and feedback were activities that provoked emotions. The teachers explored the disappointment which was brought about by failure of learners in their work and took responsibility for their own teaching. These teachers professionally learnt as they explored learners' frustrations and reflections on their teaching strategies to determine how they could have done it better. The FET Grade 12 mathematics teachers noted that giving feedback provided an explanation of what learners were doing correctly and incorrectly – whether learners transformed in their learning (Fraser et al 2007). Thus, FET Grade 12 mathematics teachers professionally learnt through frustrations experienced by both learners and themselves from assessment and feedback in their teaching roles.

From the discussion above, assessment and feedback were viewed by the participants as activities that triggered both teachers' and learners' self-introspection. The FET Grade 12 mathematics teachers realised professional learning through teaching roles as they engaged in such activities as: administering tests, marking the tests, giving back to learners their marked scripts, revising tests, as well as reacting to frustrations of learner failure. As a result, teachers professionally learnt from these activities in their teaching roles which probably enhanced their teaching and their learners' performance. The Centre for Teaching Excellence (2019) explains that feedback focuses learners' and teachers' efforts towards set targets by enabling learners and teachers to detect and remedy their errors and this process leads to teacher learning. The next section discusses the sub-theme of remedial and extension work to illustrate how FET mathematics teachers professionally learnt.

Remedial and extension work

The FET Grade 12 mathematics teachers (26) indicated professional learning experiences through remedial and extension work in their teaching roles. Remedial and extension work describes teaching roles where teachers engage their slow and gifted learners to help them achieve their learning goals (Shoemaker 2014). Remediation refers to the process of engaging slow learners in well-designed activities in response to their learning needs and to improve their learning. On the other hand, extension work relates to the ways teachers adopt for assisting their gifted learners to achieve more in their learning (Kumar 2016). Remedial work is based upon a careful diagnosis of learner defects to determine their learning needs and interests so as to take them to increased levels of competence (Kumar 2016; Cliath 2014). Kumar, views remedial and extension work as connoting teaching which is developmental in scope, hence, through such processes the FET Grade 12 mathematics teachers experienced professional learning. One of the participants, Teacher 5 during FF Interview 1 said:

> *In my remedial and extension work I learn from extra lessons. I have to consult several books to help my gifted learners. I also have the challenge to find effective strategies for the slow learners. There is need to even consult other teachers in other schools to get tasks for these learners.*

Teacher 5 above shows that remedial and extension work was demanding as it required wide reading and consultations with other teachers. Such activities provide fertile space for professional learning. These teachers provided learning support to learners who lagged behind their peers in classroom performance. By identifying alternatives or adapting teaching strategies, the mathematics teachers provided learning activities and practical experiences to learners according to their abilities and needs. The technical skill of matching teaching strategies to learner abilities remained a professional learning avenue for these teachers through teaching roles. Some (18) designed individualised educational programmes with intensive remedial support to help learners consolidate their basic knowledge in different subjects, master the learning methods, strengthen their confidence and enhance the effectiveness of learning (Mukeredzi 2009; 2015). All these efforts provided space for the teachers to professionally learn in the occupational domain of influence (Fraser et al. 2007). The sentiments above were also articulated by Teacher 1 in a PEI who said:

> *Here, (showing photo) I was in a remedial class. We were using these materials to demonstrate some circle theorem. I have learnt that one needs to be very creative and set teaching objectives suitable for these learners. I have to read widely and consult colleagues widely.*

In their teaching roles, some FET mathematics teachers in their professional learning adapted the curriculum to accommodate the learning characteristics and abilities of learners. Reviewed literature (Mukeredzi 2015) explains that remedial teachers set some teaching objectives which are appropriate to ensure that learners might acquire the knowledge as desired after the completion of each topic. Thus, FET Grade 12 mathematics teachers (26) professionally learnt through provision of remedial and extension support, activities and practical experiences including individual attention to the learners. They also learnt through their search for specialised effective teaching methods and designing relevant objectives and tasks for these remedial and extension learners.

To add on to the ideas of others above, Teacher 6 during FGD 2 said:

> *Teaching in the FET phase requires that one goes an extra mile. I do morning classes, afternoon and weekend classes to support my remedial and extension learners. While I teach, I learn to commit myself to my work and to be resourceful.*

The participant above shows that some FET Grade 12 mathematics teachers professionally learnt from their commitment and hard work during remedial and extension lessons.

Consulted literature (Hussen 2009) refers to commitment as the willingness of individuals to give their time and energy to their work. The FET Grade 12 mathematics teachers concurred that remedial and extension work required them to do more than expected of them in their teaching roles. These teachers sacrificed their time and committed themselves to this specialised teaching role which demands expert knowledge of both content and strategies (Ball 2005) from teachers. This was further explained by Teacher 5 during a FGD1 who said:

> *Remedial and extension work requires exceptional knowledge of content. At the same time, one has to be creative to manage both gifted and slow learners. The activities involved are learning opportunities for me.*

Also mentioned by Teacher 6 above, Teacher 5 identified creativity as an activity for remedial and extension work through which teachers professionally learnt in their teaching roles. Ball et al (2008) and Heuer (2017) state that expert knowledge of content and pedagogy for quality teaching is obtained through professional learning. Therefore, FET Grade 12 mathematics teachers professionally learnt through this kind of creativity. The remedial and extension work set these teachers into professional learning as they sought to have more and better strategies to enhance the learning of these slow and highflying learners (Auerback 2018). Their professional learning in this teaching role was motivated by the desire to bring learners who lagged behind their peers to the same learning level and extend the minds of the gifted learners by exposing them to new, more challenging work to extend their knowledge and skills. This is articulated by Guerriero (2017) who advocates for specialised pedagogical knowledge for teachers to create effective teaching and learning environments for students of diverse learning capabilities while in the process these teachers professionally learn.

FET Grade 12 mathematics teachers as reflected above indicated that remedial and extension work required a lot of creativity and innovation for them to help their learners achieve their goals. Thus, they engaged in professional learning through remedial and extension work as they: provided learning activities and practical experiences for learners, designed remedial programmes, accommodated learner characteristics and abilities. Remedial and extension work evoked a genuine and strong sense of commitment and focus for these teachers through their professional learning. The subsequent section further discusses professional learning of FET Grade 12 mathematics teachers through classroom management.

Classroom management

Classroom management refers to the organisation of learners in the classroom so that learning is not disturbed (Corwin 2019). Weinstein (2016) defines classroom management as the actions that teachers take to establish and sustain an environment that favours effective learning to take place. In addition, classroom management involves how teachers control variables of the curriculum, time, space and interactions with students (The Zimbabwean Ministry of Education 2015; Broderick et al. 2017). FET Grade 12 mathematics teachers (26) confirmed that they gained professional learning as they practised disciplinary strategies to maintain a classroom environment that was conducive to the learning process.

Generally, these teachers experienced professional learning in classroom management as they engaged various skills and techniques to keep learners organised, orderly and focused on their learning during instruction. Teacher 10 in the FF Interview 3 reported that: *"I learn to discipline learners. I also learn to love my learners as learners who are loved try their best to please their teacher."* The same message was shared by Teacher3 in FGD 3, who said: *"I make sure that those learners who are troublesome are monitored. I learn from maintaining class discipline as I interact with the learners."* The FET mathematics teachers as classroom leaders, administrators and managers (NAPTOSA 2016; DBE 2011) need to know how they can discipline learners in order to achieve the best results in their teaching. Discipline is the art of providing an environment in which effective teaching and learning occurs without hindrance (Byers et al. 2016; Teacher Vision 2019). Classroom discipline is a complex issue and a key concern for teachers, school administrators, students and parents (Bush et al. 2016) which also attracts significant attention from the public and from the media (Lopes and Oliveira 2017). Teachers often seek knowledge about how to discipline and motivate their learners. FET Grade 12 mathematics teachers professionally learnt through learner discipline and classroom management. These teachers indicated that they loved their learners, which increased their rapport and encouraged improved relationships with them. Surveyed literature (Pittman 2018) suggests that teachers should make sure their learners feel welcome, accepted and heard by loving them. Thus, these teachers professionally learnt in their teaching roles through their learners, monitoring them and managing classroom discipline.

The teachers concurred that the greatest challenge in classroom management was the pursuit of new and innovative ways to connect their learners to a safe learning environment and in so doing they experienced professional learning. Teacher 2 during FF Interview 1 summarised this by saying:

> *In class I learn as I reach out for ways of maintaining classroom discipline and creating a safe learning environment. If classroom management fails, then all the teaching fails. Learners need to obey classroom rules. I get these strategies from other teachers as we share experiences and as I read other people's classroom experiences.*

Professional learning here emanates from maintaining classroom discipline, creating a safe learning environment and sharing experiences with colleagues regarding how they manage their classrooms which relates to what was discussed earlier in lesson preparation. Bennett et al. (2018) reiterates that effective teachers practice good classroom management to eliminate learner disruptions. These FET teachers explained that they achieved good classroom management through interaction with learners and other teachers. They explained that they promoted a positive learning environment by teaching learners to obey rules and norms and correcting learner bad behaviour. Surveyed literature (Marzano et al. 2019) shows that classrooms which are well managed provide an environment where teaching and learning can flourish. Thus, these FET Grade 12 mathematics teachers professionally learnt from their teaching roles interaction and from managing their learners. Some teachers talked of reprimanding learners for wrong doing during classroom management. Consulted literature (Wiley 2014) indicates classroom management as a powerful factor in affecting learners' performance. In this regard, classroom management techniques are a result of teacher professional learning in their teaching roles. Frost 2019 and Fulton 2018 reiterate that effective classroom management paves the way for the teacher to realise efficacy in learner commitment to learning. Therefore, learning through classroom management fulfils the social and occupational domains of influence (Fraser et al. 2007) in professional learning as it relates to interaction of teachers and their learners, as well as the need to enhance effective teaching.

The discussion of how FET Grade 12 mathematics teachers engaged in professional learning from classroom management indicated they learnt through disciplining, loving and monitoring learners, creating a conducive learning environment, getting learners to obey classroom rules and sharing experiences with colleagues regarding classroom management. The next section discusses teacher professional learning through team teaching.

Team Teaching

Generally, team teaching relates to a scenario where some teachers collaborate to teach a group of learners. Goetz (2000) and Hargett et al. (2018) conceive team teaching as a combination of two or more teachers working together to plan, conduct and evaluate instructional programmes for the same group of learners. Therefore, team teaching is a teaching strategy where a group of teachers teach together in the same classroom, complementing one another to explain concepts to learners.

Participants (14) during data generation confirmed professional learning through team teaching as vital for their professional growth. For example, Teacher 9 during FF Interview 1 explaining professional learning through team teaching said: *"I learn through team teaching. I do team teaching with teachers from neighbouring schools. We learn from observing one another during instruction. This is effective for my professional growth."* Similar sentiments were raised in FGDs and PEIs where participants highlighted professional learning through team teaching as professional space where teachers benefitted from each other's expertise, experiences and contexts. Nguyen (2009) and Krutka (2016) view team teaching as a professional learning site necessary for enhancing teaching and learning for both teachers and learners. Through team teaching FET Grade 12 teachers professionally learnt as they observed their colleagues teaching, interacting with learners and dealing with learners' questions. These teachers also professionally learnt from how other teachers created suitable learning environments to stimulate concept formation and enhance learners' learning. There is a contention that team teaching no longer requires teachers to be in the same room, as technology has sustained professional learning through team teaching using on-line social networking groups where teachers continue to function as a team. In this way, team teaching enhances professional learning for teachers in the social domain (Fraser et al. 2007).

The discussion on team teaching raised issues of professional learning for FET Grade 12 mathematics teachers through observing colleagues teaching, observing how teachers effectively interact with learners, how other teachers responded to learners' questions and in the main how other teachers created suitable learning environments for effective teaching and learning. School meetings and seminars were another space within which FET Grade 12 mathematics teachers professionally learnt.

School meetings and seminars

School meetings and seminars were either departmental or whole-school activities that FET Grade 12 mathematics teachers engaged in, which promoted their professional learning.

Departmental meetings and seminars

During FF Interviews, all the participants confirmed having experienced professional learning through departmental meetings and seminars. One of the participants in FF Interview 1 explained professional learning through departmental seminars saying:

> *We conduct departmental seminars once a term. But if there is need in the course of the term we also meet. In these seminars we discuss topics that are challenging to teach. I learn as we discuss and facilitate in these seminars.* (Teacher 15 FF Interview 1)

Departmental seminars which were held at least once a term offered space for professional learning through discussion and facilitation of these seminars. Seminars are generally meetings where a group of teachers discuss a problem or topic of interest for their professional learning. The seminars targeted staff content gaps and pedagogical strategies for certain topics to empower teachers in their teaching roles. This was consistent with Kennedy's training and deficit models of continuing professional learning (Fraser et al. 2007). Consulted literature (Guskey 2009) encourages school workshops and advises that teachers need assistance in order to cope with challenging sections of curricular and instructional practices in their classroom contexts. Thus, from Teacher 15 during FF Interview 1, FET Grade 12 mathematics teachers professionally learnt from their content gap and pedagogical discussions which confirmed Hurrell's (2013) encouragement for mathematics teachers to understand the mathematics that they teach by sharing and interacting with colleagues.

Whole school meetings

12 teachers reported attending whole school meetings through which they experienced professional learning. For example, Teacher 11 in FF Interview 1explaining how they professionally learnt said:

> *I learn from staff meetings called by the principal. These meetings are like seminars*

as we deliberate on issues relating to our work like preparation books and work coverage. Sometimes I learn from reminders in our roles like punctuality and dress code during these meetings (Teacher 11 FF Interview 1).

12 FET Grade 12 mathematics teachers indicated that they experienced professional learning through non-formal, planned and structured whole school staff meetings and seminars where they deliberated on their teaching roles and teacher professionalism (Fraser et al. 2007). These teachers confirmed that from their seminars they professionally learnt through deliberations on professional expectations. The said seminars and meetings encouraged teacher efficacy and enhanced their attributes like professionalism, punctuality and formal dress, hence, they experienced professional learning. Teachers also developed skills and knowledge for their practice. Guskey (2009) explains that there is no improvement effort that can succeed without thoughtfully planned (Fraser et al. 2007) and well implemented staff seminars. Whole school seminars depict the concept of schools as learning organisations where they offer inclusive up-close opportunities for teacher professional learning through understanding what is happening elsewhere in the greater school system and foster inter-departmental interdependence and agency (Mukeredzi 2009). Such activities enable schools to cope with educational change and lead them towards achieving excellence. Other researchers (Johnson et al. 2010) supporting whole school seminars, report that the environment in which teachers work – physical, social and political – must be exploited during staff development seminars to yield relevant teacher behaviour. This is also enshrined in Fraser et al.'s (2007) occupational domain of influence which advocates professional learning for job specifications.

From the above discussions, school meetings and seminars offered professional learning opportunities for FET Grade 12 mathematics teachers through discussions on various issues pertaining to their work and professional expectations. This portrayed schools as learning organisations for teacher professional development. The next discussion covers how FET Grade 12 mathematics teachers engaged in professional learning through in-school research activities.

Research

Teachers are generally faced with a multiplicity of professional issues that require them to research with a view to fostering effectiveness in their practice. This is consistent with Fraser et al.'s (2007) action research model of continuing professional learning. Research refers to a careful study that individuals do to discover facts and information about their work (Cannon 2017). It is a quest for a better understanding with a view to excel in their work which must be consistent with progress in national development (Luft and Hewson 2014). Nine of the FET mathematics teachers indicated that they professionally learnt through research to enhance effectiveness in their teaching. For example Teacher 15 during FF Interview 1explained that:

> *I learn through research … for successful lesson delivery. This I do to keep up to date with the changes that continue to occur in education. It is important to give learners the correct and current information when I teach.*

21 participants in different FDGs articulated similar views. Teacher 2 during FGD 2 said: *"I learn through research by consulting a variety of textbooks for my lessons. This helps me to choose live and good examples during teaching and to teach relevant and accurate content."* Most of the participants in the FF Interviews commented that research was a professional learning tool that enhanced lesson delivery and kept them abreast of current information. This enhanced teacher professional learning. Surveyed literature (Norris 2012; Vorderman et al. 2011) reports that mathematics is widely applied in society and reference to current application of mathematics during teaching makes it alive and relevant to national development. Some of this information could only be understood through reading and research. Teachers also conducted research in order to understand their contexts and know how to handle their teaching situations. Ping and Schellings (2018) in support encourage teachers to conduct research in order to familiarise themselves with their contexts and to know their roles. The participants explained that research promoted their professional learning and they were able to choose live and relevant examples which could support the development of concepts in their teaching. Therefore, FET Grade 12 mathematics teachers also professionally learnt through research as they read widely about mathematical topics in search of better ways of teaching concepts to learners.

Two other participants, Teacher 3 during FGD 3 and Teacher 7 in FF Interview 1, expressed similar sentiments about learning from research through social media. In a FGD one of the participants said: *"I am always on the social media learning from various educational programmes in order to prepare for my lessons"* (Teacher 3 FDG 3). In addition, the other participant in the FF Interview also reported that:

> *I am always on social media researching about mathematics teaching. I learn new*

> *content and better strategies of teaching in mathematics from articles and other teachers. This is important for me to improve my competence.* (Teacher 7 FFI interview 1)

The participants above allude to professional learning through research from social media in their teaching roles. Social media is generally on-line channels of communication based on people's inputs, content-sharing, interaction and collaboration. This is professional learning founded in the social domain of influence (Fraser et al. 2007). From literature, Dollarhide (2019) defines social media as a social-networking internet-based facility that enables users to access quick electronic communication of content. Research through social media exposes FET teachers to ideas of other researchers about content and teaching strategies for their teaching. Literature surveyed (Konen 2017) shows that through these practices teachers prepare innovative and creative lessons. Further, literature surveyed (Khan 2019; Hermans et al. 2008) emphasises teacher professional learning through research on social media as critical for varying teaching methods and strategies during pedagogical practices. Thus, these FET Grade 12 mathematics teachers professionally learnt through reading on-line mathematics journals and articles, as well as observing other teachers do their work on social media.

Seven FET Grade 12 mathematics teachers reported that they realised professional learning through research done by their learners. Teacher 7 FGD 2 reporting how they professionally learnt from research by their learners said: *"I encourage my learners to research. I learn from their research. I provoke them to read more and discover more about what they have learnt."* Learner research enabled some FET Grade 12 mathematics teachers to realise professional learning. The participants reported that in their teaching roles they encouraged their learners to research in order to construct more knowledge. Usually, when learners discover new content, they want to confirm it with their teachers and such experiences lead to teachers professionally learning. Teacher professional learning through research is vital to support the development of professional skills for teaching (Hammond et al. 2017).

18 of the 26 FET Grade 12 mathematics teachers also indicated that they had experienced professional learning from answering questions raised by their learners during lessons and out of class. Teacher 5 during FGD 1 reported that: *"I learn from research through the questions that learners ask about their work during and after lessons".* The idea of teacher learning from learners' questions was popular with most participants in FGDs and FF Interviews.

These teachers experienced professional learning as they began to search for answers to these questions. Reviewed literature (Cotton 2019) indicates questioning as any statement that has an interrogative nature and is central to meaningful learning. Literature (Chin 2008) argues that asking good questions is critical to learning and sometimes remains more important than finding answers to the questions. For FET Grade 12 mathematics teachers, learner questions became indications of deficiencies in their teaching which informed their professional learning and prompted them to search for information to plug such deficiencies.

From the discussion above, some FET Grade 12 mathematics teachers (12) reported that they experienced professional learning through research done by learners, through social media and from learner questions. From research, the FET Grade 12 mathematics teachers also realised professional learning through reading widely, learning new content and discovering new methods of teaching. These teachers also professionally learnt from research on social media through social networking with colleagues. How FET Grade 12 mathematics teachers engaged in professional learning through the use of technological sources is discussed in the next section.

Technological sources

Use of technological sources

Generally, FET Grade 12 mathematics teachers have a responsibility to embrace the opportunities presented by technology in order to enhance their professional learning and improve their competences in their teaching roles. Technology connects teachers to other people, to data, content, resources, expertise and learning experiences (Kendal 2019) that empower and inspire them to effectively teach their learners (occupational domain) (Fraser et al. 2007). Technological sources which expose teachers to professional learning cover all materials, tools and techniques (Tally et al. 2017). Application of technological sources promoted their professional learning through research, as they discovered new knowledge through the use of gadgets and software. Researchers consulted (Billy and Laura 2019; Laurillard 2013) propound that as technology integration continues to increase in society, teachers must possess skills and behaviours that will increasingly connect them to a global and digital society. Technological sources include e-books, white board, television, computers, cellphones and the internet. 24 FET Grade 12 mathematics teachers explained that they professionally learnt through the use of such technological sources in their teaching roles. Professional learning through use of technological sources in this section is discussed under the internet, other technological resources and technological knowledge.

The internet

Reports from all the FET Grade 12 mathematics teachers (23) exhibited that they professionally learnt through the internet. The internet is usually known as electronic computer-based technology which facilitates the sharing of ideas, thoughts and information through social-networking. Opreaa (2014) refers to the internet as a tool that is available to anyone, anytime and anywhere in the world to access information of their choice. Fraser et al. (2007) present this as professional learning for occupational needs as teachers learn to keep themselves accessible to new and better ways of teaching. This is supported by Brownstein (2004) who reiterates that the internet is a tool that can generally be used with any educational theory. To explain how FET Grade 12 mathematics teachers professionally learnt from the internet, Teacher 3 during FF Interview 1 reported that: *"I read my e-books and peruse the internet to learn other ideas about the subject content that I teach. I do this to learn how other people from elsewhere teach different topics."* Teacher 5 during FGDs in support said*: "I learn a lot from wide e-reading and browsing the internet about my work. I learn how other teachers do things differently."* From the comments, the FET Grade 12 mathematics teachers read e-books and perused the internet to read materials from other teachers related to content and pedagogy. The internet offered them exposure to huge content and pedagogical information, thus, their professional learning, which promoted their work. Reviewed literature (Brownstein 2004) confirms that the internet offers powerful and varied ways for teachers to learn from. Brownstein further indicates that the internet accesses a broad base of resources from which these teachers can benefit through professional learning without time and location limitations. Besides, these teachers through the internet may share tests, assignments and even examination question papers (Koehler and Mishra 2009; Leendertz et al. 2013) useful for internal learner assessment. Thus, all these processes promote teacher professional learning.

Through the internet the FET Grade 12 mathematics teachers experienced professional learning through informal activities (Fraser et al. 2007) such as perusing relevant and current information about teaching, reading e-books, perusing the internet to access materials from other teachers and organisations and sharing tests and question papers for assessment on social media. These teachers reported professional learning through technological resources.

Technological resources

Data shows that some FET mathematics teachers (16) experienced professional learning through technological resources. Technological resources are referred to as physical materials and equipment, software and educational policies, which are used to facilitate learning and improve teacher performance (Koebele and Harris 2019). Technological resources can also be perceived as tools which are used to explore and facilitate learning through the internet and other avenues of professional learning. Koebele and Harris contend that technology in the classroom is not just a tool but a resource for getting information which further promotes teacher professional learning. Surveyed literature (Kamba 2007) advances that technological resources in teaching make teachers and students' communication more convenient and interesting. 16 of the FET Grade 12 mathematics teachers reported that they experienced professional learning through some technological gadgets that they used in their teaching roles. Teacher 5 during PEI reporting their professional learning through the use of technological gadgets said:

> *I was doing a power point presentation of a lesson on Trigonometry (showing a photograph). … I learnt that when I do power point presentation learners get alert and motivated to learn* (Teacher 5 PEI).

Another participant, Teacher 7 during FF Interview 1, supported the sentiments above saying:

> *I have learnt that when I use the whiteboard learners want to get chances to demonstrate to others on the board more than when I use the chalkboard.*

Similar ideas were echoed by participants during FGDs when Teacher 2during FGD 1 explained that:

> *I learnt that learners like to use the whiteboard more than the chalkboard. When I use the computer in class all learners become motivated and interested. I also learnt that when learners see me comfortable on the computer, they gain confidence in me and become motivated* (Teacher 2 FGD 1).

All the participants from all data generating sources experienced professional learning from the use of technological resources in their teaching roles. The FET Grade 12 mathematics teachers discovered that technological resources attracted learner attention and enhanced the teaching and learning process in their classrooms. The whiteboard stimulated learner interest to participate in demonstrations, while power point presentations developed learner confidence in the teacher. In this study, the whiteboard referred to a smooth glossy sheet of white plastic used by teachers to write on using a coloured pen or marker (Inouye 2017). Power point presentation also uses another type of whiteboard which is defined as an interactive screen display that is connected to the computer and allows viewing, input and collaboration by multiple users. The use of computers by teachers in their teaching aroused learner confidence in their teacher and this encouraged these teachers to engage more in professional learning. Surveyed literature (Lester 2018) suggests that the use of technological resources improves teaching styles and can simplify some of the tasks that usually frustrate teachers. Therefore, technological resources are sources of professional learning for teachers in their teaching roles. Mishra and Koehler (2009) in conceptual frameworks highlight that technological resources stimulate teaching and learning in the classroom and beyond.

Some of the FET Grade 12 mathematics teachers (8) also indicated professional learning through the use of the whiteboard. For example, Teacher 7 in the PEI elaborated:

> *Learners have become technologically oriented. I have learnt that working from the chalk board does not excite them any-more. These days I use my white board and power point for teaching. I learnt that when I use these technologies the learners pay attention and learn better.*

Alberth and Mursalim (2014) arguing for the use of media describe it as a conduit for learning which opened up avenues for sustainable teacher professional learning. Professional learning through the use of media is transmissive in nature (Fraser et al. 2007). These participants acknowledged that their learners had embraced the use of technologies for teaching and learning and teachers experienced professional learning from that experience. The FET Grade 12 mathematics teachers professionally learnt that the use of technologies attracted learners' attention. Paying attention during instruction enhances effective teaching and motivates teachers in their roles.

To illustrate how they further experienced professional learning through the use of technologies Teacher 5 during FF Interview 1 said:

> *Sometimes we just sit down together to watch television. Watch a game of soccer over a drink. This is very common for me and my colleagues. As we relax, I find myself learning from discussions about our work and learning from the activities in the games we watch.*

The television tended to pull colleagues together for entertainment and learning. When they met they sometimes discussed issues relating to their work and this brought about professional learning from each other and from what was being watched which may have included watching mathematics teaching channels like Channel 911 alluded to by Teacher 5 earlier. Such kinds of collaboration led to collaborative reflections which in turn brought about professional learning. Literature surveyed (Mukeredzi 2014) indicates that collaborative reflections require an attitude that values personal and intellectual professional growth of oneself and of others. This appeared to have been the case in this context where teachers relaxed together, watching and sharing. Thus, these teachers realised professional learning through use of the whiteboard, chalkboard and power point presentations in their teaching roles. Teachers used their technological skills to operate technological resources.

Technological skills

Technological skills enable teachers to access information for their professional learning in their teaching roles. Technological skills are often regarded as the abilities that individuals possess to manipulate technological resources for their benefit. All FET Grade 12 mathematics teachers indicated that they professionally learnt as they manipulated the available technological resources to access information about their practice. This is consistent with Bell and Gilbert's (2005) occupational domain of influence where teachers professionally learn to enhance their occupational practice.

The participants explained that after accessing information they downloaded and printed it for their learners. Teacher 3 in FGD 4 elaborated that: *"I learnt from materials that I access, download and print for my learners. These are materials that I find fitting for my learners too."* The FET Grade 12 mathematics teachers professionally learnt through accessing, downloading and printing information for use in their teaching duties. Thus, the teachers experienced professional learning through this information from on-line communication networks. Manca and Ranieri (2014) view the use of technological resources as social capital for bridging and bonding educational activities which facilitates coordination and cooperation for the benefit of teaching professionals. In addition, the conversations that the teachers held with one another through cellphone chats offered them some professional learning. However, researchers Leendertz et al. (2013) argue that the use of technological sources continue to threaten teachers as they remain technically challenged to use them.

The use of technological sources by FET Grade 12 mathematics teachers discussed above was perceived as an innovation in their teaching roles which offered significant professional learning. Through these technological resources, participants realised professional learning in the comfort of their homes, their times and contexts. Researchers consulted (Antunes et al. 2011) assert that the use of technologies in professional learning is vital for connecting, communicating, sharing and collaborating the pillars of knowledge development among teachers.

Further, all the FET Grade 12 mathematics teachers' professional learning was experienced through wide e-reading, perusing the internet, using such resources as the whiteboard, power point, traditional chalkboard, the computer and watching educational television programmes. These teachers also realised professional learning through technological skills of accessing, downloading and printing information for learners from on-line communication networks. Thus, Koehler and Mishra (2009) and Leendertz et al. (2013) advocate for knowledge of technology as paramount in integrating other forms of knowledge in teacher professional learning. The use of such resources as the whiteboard, power point presentation and the use of i-pads in the classroom enabled teacher renewal and enhanced these teachers' self-esteem. Data further indicated that professional learning for FET Grade 12 mathematics teachers also occurred through additional roles assumed.

Additional roles

Additional roles are responsibilities that teachers engaged in which complemented their teaching roles. Such roles which were assigned to FET Grade 12 mathematics teachers included participation in co-curricular activities, assisting in the principal's office, membership in school management teams, chairing of sports committees, learner support, conducting assemblies and other administrative roles. From my theoretical framework, these duties are formal and planned (Reid's quadrants), as well as social and occupational (Bell and Gilbert's domains of influence) responsibilities (Fraser et al. 2007). The next section discusses professional learning for these teachers through co-curricular activities.

Co-curricular activities

The FET Grade 12 mathematics teachers (15) involved in co-curricular activities indicated that through such roles in sports and other designated school duties they gained team-building and management skills necessary for effective instruction. Co-curricular activities refer to activities that teachers engage in within the school but outside the classroom which complement and support the curriculum (Robert 2018). These were activities from which teachers professionally benefitted as they developed learners' skills through coaching teams in ball games and athletics, debates and drama. Education Reform (2014) regard co-curricular activities as responsible for facilitating the development of domains of the mind and the personalities of those who take part. Thus, through engagement in these activities teachers experienced professional learning.

Teacher 7 in FF Interview 1 explaining how they professionally gained from co-curricular activities reported: *"I learn from co-curricular activities as a softball coach. I learn more about the abilities of my learners as they freely play with each other."* Participants from the focus group discussions complemented the sentiments above as Teacher1 during FGD 3 said: *"I learn as I train my learners in soccer. The learners develop communication skills and work together as a team."* These teachers experienced professional learning during co-curricular activities through coaching. The teachers got to understand their learners better through their learning and developed communication skills which were vital for classroom instruction**.** Literature surveyed **(**Education Reform 2014) indicates teacher professional learning through enabling learners to express themselves freely, inculcating the values of respect, empowering learners in decision-making, providing chances of socialisation and others, as best acquired through co-curricular activities and significant for professional efficacy.

In the same vein, Roberts (2018) argues that learning through engaging in physical activities is emphatic and permanent among participating individuals. To illustrate learning through co-curricular activities, Teacher 10 during PEI said:

> *I train volley ball. I learn learners' attributes as I watch them in training and see them talk to each other. Learners enjoy volley ball and when they play I get a chance to learn about them in their natural state.*

The Participants (15), apart from experiencing professional learning from coaching, also learnt from observing out-of-class learner characteristics during these extra-curricular activities. Consulted literature (Robert 2018) explains that play promotes frankness and clarity in language and develops personalities of learners and teachers. In addition, these FET Grade 12 mathematics teachers experienced professional learning related to learner attributes related to play. The knowledge of learner attributes confirms theory (Fraser et al. 2007) which urges mathematics teachers to learn for their personal and social needs.

Thus, professional learning for these teachers occurred through analysing learner characteristics which led to identification of examples that could be used to demonstrate specific mathematical facts and theories during instruction. Again, from co-curricular activities these teachers experienced professional learning through participation in coaching, communication with learners and reflection on learner attributes. Other FET Grade 12 mathematics teachers experienced professional learning through administrative roles.

Administrative roles

Administrative roles in this study refer to those duties that teachers performed in assisting the school principal from which they experienced professional learning. A few of the FET Grade 12 mathematics teachers (5) were exposed to professional learning through their involvement in administrative duties. One of the participants commented:

> *I am responsible for discipline and punctuality in the school. I learn as I teach learners to be disciplined and punctual for school activities. I am a member of the SMT. I am also in the functions committee and I learn a lot in these portfolios* (Teacher 4 during FF Interview 2)

The participant above experienced professional learning through participating in the school management team, being a member of the functions committee and managing learner punctuality and discipline in the school. Other FET Grade 12 mathematics teachers were responsible for some specific administrative roles in the school. The main role of administrative personnel is to oversee the daily school operations (Bruens 2012). Meador (2019) identifies handling student discipline as the main role of those in school administration. Thus, some of these FET Grade 12 mathematics teachers took up these assigned responsibilities in the school and experienced administrative professional learning.

As far as administrative roles are concerned, these teachers professionally learnt through maintaining discipline, encouraging punctuality and participating in decision making.

Another aspect which offered the FET mathematics teachers professional learning was engagement in learner support programmes which are discussed below.

Learner support

18 of the FET Grade 12 mathematics teachers reported experiences of professional learning through supporting their learners to realise their educational goals. Learner support refers to the assistance that learners get from their teachers for their learning, other than the obvious instruction and skills development (Selikow et al. 2014). It generally involves efforts that teachers engage in to relieve learners from pressure that mounts on them through formal school work and other demands in their learning experiences. The activity offered teacher professional learning through teacher creativity and innovation which stimulated learner learning. Das et al. (2014) identifies several factors that prompt the need for learner support: limited access to information; lack of appropriate environment for study; need for proper guidance; time constraints; and family, social and work obligations.

The majority of the FET Grade 12 mathematics teachers (18) indicated that they professionally learnt through learner support in various activities they engaged in. Teacher12 in FF Interview 1 illustrating how they learnt from learner support said: *"I learn from organising prize giving days every year. The prizes are given to excelling learners in academic work and sport."* Also, Teacher 13 during PEI explaining the same added: *"I learn through career guidance as learners choose the subjects for the careers that they want to do. Through this, these learners develop a positive attitude towards their school work."* These FET Grade 12 mathematics teachers realised professional learning through their involvement in prize giving and career guidance programmes. Consulted literature (Regent 2019) views teacher learning from prize giving and career shows as central to teacher focus and as a guide towards learners' educational goals. This provides pointers to how teachers may guide their learners and professionally learn in the process.

Helping learners secure places in tertiary institutions was reported by some FET Grade 12 mathematics teachers (7) as another space from which they experienced professional learning. One teacher in a FGD elaborated: "*I learn as I help learners with their applications. Helping learners with their applications builds strong teacher/learner relationships. I learn from these teacher/learner relationships*" (Teacher 3 FDG 4). Thus, their professional learning in this regard was through supporting learners with their applications, which improved rapport with their learners. Chattopadhyay (2014) reiterates that learner support is necessary to improve access to information and provide guidance to learners in their education. Improving access to information and providing guidance to learners, thus, offered these teachers great opportunities for professional learning in the social and occupational domains of influence (Fraser et al. 2007).

Regarding learner support discussed above, the FET teachers gained professional learning through creating rapport with learners, improving learner access to information and providing guidance to learners. In their additional roles, some of the FET Grade 12 mathematics teachers engaged in professional learning through conducting school assemblies.

Conducting assemblies

Conducting assemblies is usually an activity that teachers do to guide the moral behaviour of learners in the school. School assemblies are gatherings intended to create strong well bonded school communities (Education World 2019). Such activities presented opportunities where a large group of members of the school community celebrated being together (Anderson 2018). Teachers did some devotions and made announcements including clarifying and emphasising school rules and regulations during assemblies. This process consequently exposed them to professional learning and developed their skills in handling the whole school staff and learners. Teacher 10 during FF Interview 1 explaining how they learnt through assembly said: *"I learn from conducting assemblies. At assembly I learn from the devotions. Here we teach moral behaviour to the learners".* This was supported by Teacher 5 during FGD 3 who said: *"I learn from announcements and explaining school rules and regulations to learners during assemblies."* 23 FET Grade 12 mathematics teachers confirmed having experienced professional learning through the process of conducting school assembly. The Education World (2019) explains that school assemblies are informative and entertaining and they prepare learners for concentration to study. Through the process of conducting assembly these teachers learnt from organising learners for devotions, instilling order and preparing the learners' mind-sets for learning. This was consistent with the transformative mode of professional learning (Fraser et al. 2007). So, these teachers professionally learnt as they engaged themselves in conducting assemblies and sought to prepare learners for their learning.

From the discussion above regarding within school professional learning sites, FET Grade 12 mathematics teachers engaged in professional learning through classroom practice, school meetings and seminars, research, technological resources and additional roles. In relation to classroom practice, FET Grade 12 mathematics teachers engaged in professional learning through such activities as lesson preparation, lesson delivery, assessment and feedback, remedial and extension work, classroom management and team teaching. Regarding lesson preparation these teachers professionally learnt from reading textbooks, consultations and discussions with colleagues, working out mathematics problems, reflecting on previous lessons, planning the lessons, watching demonstration lessons on television and considering learners' input. Lesson delivery offered professional learning through organising for the lessons, observing and monitoring learners during lessons, using different teaching strategies, interacting with learners, brainstorming questions and the use of games which promoted the teachers' effectiveness in their teaching roles.

Further, these teachers professionally learnt from assessment and feedback through self-introspection, administering tests, assignments and examinations, giving learners feedback and detecting and remedying learners' errors which improved their competence and attainment. Through remedial and extension work the teachers learnt as they prepared suitable remedial and extension activities which accommodated learners' characteristics and abilities. The FET mathematics teachers also learnt from disciplining, caring for and monitoring learners, creating suitable learning environments, enforcing classroom rules and sharing with colleagues classroom management experiences. These processes strengthened teaching and promoted learner compliance.

Through school meetings and seminars, the FET Grade 12 mathematics teachers professionally learnt as they engaged in departmental meetings and seminars organised to address teacher gaps in both content and pedagogy. In their teaching roles, these teachers engaged in whole school meetings where they experienced professional learning related to professionalism and collegial relationships. This they said developed their professional ethics and attributes. Through research the FET Grade 12 mathematics teachers experienced professional learning from perusing social media and reading widely therefrom. Technological resources also offered these teachers professional learning as they used the internet, technological resources (whiteboard, computers, power point) and applied technological skills in their teaching.

Lastly, from additional roles the teachers professionally learnt through engagement in co-curricular activities, administrative roles, learner support and conducting school assemblies. During co-curricular activities these teachers experienced learning through coaching learners in various sporting disciplines, while in administrative roles managing punctuality and discipline of both teachers and learners created space for professional learning. Regarding learner support, these teachers gained professional learning through organising prize giving programmes, career guidance and managing learners' challenges. As they conducted assemblies these teachers experienced learning through conducting devotions and giving social and moral guidance to both teachers and learners. Having discussed professional learning within the school site, the following section discusses how FET Grade 12 mathematics teachers reported professional learning from wide professional sites.

PROFESSIONAL LEARNING WITHIN WIDE PROFESSIONAL SITES

Professional learning through wide professional sites was experienced through non-formal planned or unplanned meetings (Fraser et al. 2007) and workshops, organised by the cluster, district, province or staff associations where participants were not formally accredited for their learning. These professional learning sites enable teacher professional learning which is credited with professional development points on a three-year cycle by the South African Council of Educators (SACE) as highlighted in Chapter One. Within wide professional sites were also informal sites such as social media, social gatherings and other informal interactions at sports fields, in bus, at the shops and in the corridors. Participants experienced professional learning through all these non-formal and informal interactions as identified in my theoretical framework (Fraser et al. 2007). Informal professional learning included interactions with colleagues and technologies informally and may exist even within non-formal contexts (Eaton 2012). Data shows that most of the reports about professional learning within wide professional sites for these teachers came from FF Interviews and FGDs. Reports from PEIs were minimal regarding this learning space as most of the participants (11) took photographs of those aspects that depicted their professional learning within their teaching roles in their schools. However, with regard to wide professional sites, this section discusses professional learning through workshops (cluster, district and provincial), social gatherings and collaboration with other schools. These themes are discussed in turn below.

Workshops

Workshops are all the activities organised for teachers to enhance their capacities to execute their teaching roles effectively (Guskey 2009). These are non-formal activities which are facilitated by the teachers themselves or some chosen outside experts with a view to covering some identified professional need for a group of teachers (Kelly 2006). During data generation all the FET mathematics teachers indicated that they professionally learnt through workshops organised in their clusters, district and province which are discussed below.

Cluster workshops

All the FET mathematics teachers experienced professional learning through subject specialisation cluster workshops. A cluster is a group of schools within close geographical proximity of each other which shares ideas, resources, pedagogies and challenges all intended to improve teacher professional development, education quality and relevance in respective institutions (Mukeredzi 2015; Chikoko 2009). Cluster workshops were, therefore, workshops organised for a group of teachers from such schools to address a common professional issue in their subject specialisation (Blasé & Blasé 2006), in this case mathematics. From the data, the FET Grade 12 mathematics teachers indicated that they attended cluster workshops and meetings from which they learnt professionally. Explaining such professional learning, Teacher 15 during FF Interview 1 said:

> *I learn from cluster workshops that are organised by our cluster leader and subject advisor. I also learn from cluster moderations, subject planning and content gap filling meetings. We organise fellow teachers to facilitate in those workshops.* (Teacher 15 in FF Interview 1)

Schools in one cluster are often distinguished by some common tendency in their professional roles such as administering common tasks to learners, planning together and common pacing on curriculum coverage. In this context, professional learning is done to fulfil job requirements, hence, occupational needs (Fraser et al. 2007). The FET Grade 12 mathematics teachers attended and participated in cluster workshops and meetings where they professionally learnt through moderation of marking of formal tasks, planning for topics they taught and staff developed each other in these areas of their roles. Content gap filling refers to discussions that these teachers engaged in to teach each other those topics where they had knowledge gaps and this offered them professional learning. In this regard, professional learning for these teachers was consistent with the deficit model of continuing professional learning (Fraser et al. 2007). Wang and O'dell Schwille (2008) in the literature reviewed illustrate that workshops must improve personal comfort levels with content challenges and adjust teachers to the cultures of their schools. Consequently, FET Grade 12 mathematics teachers engaged in professional learning through these workshops and meetings within their teaching roles in order to enhance their practice.

This discussion on FET Grade 12 mathematics teachers' professional learning through cluster workshops demonstrates that these teachers experienced learning as they attended cluster meetings, conducted workshops for content and pedagogy and for common marking and task moderations. The following section discusses professional learning that the teachers engaged in through District workshops.

District workshops

Data from individual face-to-face interviews and focus group discussions showed that all the FET Grade 12 mathematics teachers in this study engaged in professional learning within their roles through these district workshops. District workshops are workshops that are organised and conducted at district level for all or some clusters in the district. Generally, there are workshops and meetings that are conducted to advise teachers about new policies or to cascade information regarding changes in curriculum. For FET Grade 12 mathematics teachers these were professional learning opportunities where changes in curriculum and policies would be transmitted at once to a large group of teachers. From the theoretical framework professional learning was transmissive (Fraser et al. 2007). However, cascading information top down through professional workshops has been criticised for dilutions and distortions which emanate from misconceptions and omissions by facilitators (Ono and Ferreira 2010). Teacher 4 in FGD 3explaining how they learnt said: *"At the district I learn from subject meetings. I also learn from workshops especially when there are new changes in the subject, like when there are curriculum shifts."* A similar message was conveyed by another participant who said:

> *Every beginning of the year we meet as maths teachers in a subject meeting to review the matric results of the previous year. Teachers from schools that performed well are given an opportunity to share with other teachers their experiences and good practices so that we can all learn from them* (Teacher 4 during FDG 2).

Sharing experiences and good practices creates space and time for these FET teachers to communally reflect on their work, share experiences and challenges, find common ground, empathise and connect with one another (Sayed 2016) and, consequently, professionally learn. Through their connections and interactions, these teachers were able to get over their barriers in their teaching roles and to achieve professional learning. In some instances, the lead teachers (subject advisors) would identify problems around teaching roles which they would bring into these workshops yet they would not benefit the teachers in their roles. However, most of the participants agreed that sharing good practices was a noble idea from which FET mathematics teachers, consequently, engaged in professional learning.

Another participant in support added:

> *Sometimes I learn from workshops called to discuss a common problem in the teaching of a certain topic. I also learn from subject meetings organised at every beginning of year to map the way forward* (Teacher 5 during FGD 2).

FET mathematics teachers through professional learning workshops benefitted from discussing common problems from identified topics and subject meetings. These activities provided continuous learning for these teachers. Thus, SACE (2016) stresses that administrators should encourage their teachers to continue with their education and create opportunities for their professional learning.

From discussions on workshops and meetings the FET Grade 12 mathematics teachers reported that they professionally learnt from organised district workshops and meetings. Ko, Ward and Wallhead (2006) concur that workshops deepen and extend the teachers' teaching practices and subject matter. As such, these teachers experienced professional learning through workshops and meetings. The teachers were also involved in provincial workshops where they experienced their professional learning.

Provincial workshops

Another space from where all the FET Grade 12 mathematics teachers experienced professional learning in this study was through workshops organised at provincial level. Like district workshops these were conducted to advise teachers about any new policies, to cascade information regarding changes in curriculum or to help teachers with difficult topics. All the participants indicated that provincial workshops were irregular. However, whenever they occurred, they were fruitful. Teacher 16 in FF Interview 1 explaining this said: "*We rarely have provincial workshops. However, they are sometimes conducted to discuss new policies or new content. I learn new content and policies from these workshops"* (Teacher 16 during FF Interview 1). Teacher 12 during PEIs added that provincial workshops are scarce saying: *"There was one provincial workshop held last year. I learnt the content on financial maths and probability and the different ways of teaching these topics."* Zambo and Zambo

(2008) allege that there is an on-going need for teachers to professionally learn especially in mathematics since mathematics is a focus area for national development. Usually, professional learning would keep FET Grade 12 mathematics teachers well informed about their subject matter through workshops, hence, these provincial workshops needed to be more regular. From theoretical framework (Bell and Gilbert 2005), such gatherings have the capacity to manipulate teacher beliefs and instil in them the necessary confidence in their work. Generally, professional learning at this level has the capacity to re-focus the teachers' mind-sets towards educational goals. Hill (2019) asserts that school improvement is heavily dependent on teacher professional learning. These teachers experienced professional learning through these scarce provincial workshops. However, it must be noted that scarcity of provincial workshops and lack of monitoring of these workshops relaxes the momentum of teachers' commitment to their teaching roles.

Generally, FET Grade 12 mathematics teachers professionally learnt from workshops at three levels: cluster, district and provincial. However, it would appear that these workshops were not regular and were done from the assumption that superiors had about the teachers' problems rather than from the real needs of these teachers. Nevertheless, these teachers gained professionally from the workshops. Social gatherings also offered the FET Grade 12 mathematics teachers some professional learning as the following sections illustrate.

Social gatherings

In this study, social gatherings are perceived as groupings that occur within communities, friends and colleagues, intended or unintended from where teachers find themselves professionally learning. WorldNet (2006) defines social gatherings as those gatherings for the purpose of promoting fellowship. They are usually sources of collective wisdom and establishment of connections which set a context for sharing social and sometimes professional knowledge within their communities (Sayed 2016). This theme will be discussed below through the following sub-themes: sharing experiences and good practices; community involvement; and informal collegial meetings.

Sharing experiences and good practices at gatherings

Data shows that FET Grade 12 mathematics teachers experienced professional learning from social gatherings through sharing experiences and good practices. Vrieling (2018) recognises that teachers' social experiences stimulate their professional learning. In this study sharing experiences and good practices were understood as social professional learning by FET Grade 12 mathematics teachers regarding their situations and circumstances. These learning experiences through social gatherings that occurred within wide professional sites were spontaneous and interdisciplinary and provided avenues for professional learning. Literature (Claibome 2019) confirms that discussions that occur when professionals meet are always effective and dependable sources of teacher learning. Discussions during data gathering sessions showed that whenever mathematics teachers met they always shared their work experiences and good practices and learnt from those interactions. All participants during FGDs, FF Interviews and PEIs reported that they shared their experiences and professionally benefitted whenever they met. For example, Teacher 5 during FF Interview 1 said: *"When I meet my colleagues, be it in the shops or at some gathering, we tend to share our work experiences. I learn from these discussions we make as friends and colleagues."* The idea was also expressed by Teacher11during PEI who said: *"I learn from discussions I make with friends when we meet in the streets. We ask each other about our work and advise each other when it's necessary to do so".* Claibome (2019) and Vrieling (2018) confirm that these spontaneous meetings are powerful for teacher professional learning spaces as they offer learning without pressure to learn. Such learning, which was voluntary and self-propagated, received all the attention that made benefits of the learning well accommodated.

From discussions on social gatherings FET Grade 12 mathematics teachers learnt in their roles through discussions with colleagues, sharing experiences about their work and seeking advice from one another about challenges in their teaching roles. The section that follows covers professional learning through community involvement.

Community involvement

17 FET Grade 12 mathematics teachers also engaged in professional learning through their participation in their communities. Preston (2018) views community involvement as an interactive process that generates social connections between educators, learners and parents. Community support of any education system has the effect of influencing learner performance and functioning of the schools (van Roekel 2008). In this study community involvement refers to the participation of teachers in community activities such as social games, funerals, wedding ceremonies and *imigidi* (circumcision ceremonies), which were often informal, planned and unplanned from where they benefitted some professional learning. Again, community involvement relates to participation of parents and communities

in defining and shaping the education of their children (Mkhabela 2008). Reports by 17 teachers indicated that taking part in community activities created positive relationships with the communities in which teachers lived and worked. Teacher 4 during FGD 1 in explaining how they experienced professional learning through their involvement in communities said: *"I learn the cultures and backgrounds of my learners as I attend community functions such as funerals, imigidi, other cultural functions and weddings."* Research by van Roekel (2008) and Mkhabela (2008) indicate that partnerships between teachers and their communities improve schools, increase teacher learning and learner performance. Teacher participation in community functions also enhances the development of a bond between teachers and their community and fosters trust among them. Hence, FET Grade 12 mathematics teachers indicated that through these gatherings and functions they professionally learnt about the cultures and backgrounds of their learners. The learning of cultures and values created an environment for effective learner learning and stimulated teacher professional learning. Consequently, these teachers professionally gained knowledge on how to manage learner behaviour and attitudes.

From discussions above, teacher involvement in the community exposed the FET Grade 12 mathematics teachers to professional learning through attending community funerals, imigidi, other cultural functions, games and weddings. These teachers also realised professional learning from informal collegial meetings which are discussed below.

Informal collegial meetings

Drawing from Reid's quadrants (Fraser et al. 2005) informal collegial meetings refer to such activities as corridor and staffroom chats from which FET Grade 12 mathematics teachers professionally learnt. These meetings occurred when teachers met in spaces such as in the bus, at the shops, at the sports field, in the streets or in school corridors and began to talk about their work (Jones and Dexter 2014). This kind of learning also took place during workshops and seminars as informal professional learning always sits at the verge of planned, organised, formal gatherings. All FET mathematics teachers explained that they learnt through such spontaneous meetings both in school and out of schools. Teacher14 in FF Interview 1 explaining how they learnt said:

> *I learn from colleagues that I meet when I take a walk to the shops or just relaxing. Sometimes I learn as we discuss certain learners who give us problems in the classroom. How does so and so do in your class? How is his/her performance?*

(Teacher 7 FF Interview 1)

Similar sentiments were also expressed by Teacher 5 during FGD 1 saying: *"I learn from other colleagues when they share their experiences about some learners in their classrooms."* These teachers showed that informal meetings were powerful learning opportunities from which professional learning occurred. Reid's spheres of influence (Fraser et al. 2007) view informal sources of professional learning as important in influencing teacher behaviour. Reviewed literature (Langveld 2016) indicates that informal teacher interactions are becoming an effective means of promoting peer learning among practising teachers. The FET Grade 12 mathematics teachers reported that they discussed events that took place at their workplaces which offered professional learning gained from each other's experiences. Another participant (Teacher 2 FGD 1) explaining how these teachers professionally learnt through informal meetings said:

> *I learn as we talk over a drink with my friends. Most of my friends are colleagues. We find ourselves talking about our work asking each other about our common tests and examinations. Sometimes we exchange tests or discuss some challenging questions* (Teacher 2 FDG1).

The comments above confirm professional learning of these FET Grade 12 mathematics teachers through informal meetings. Jones and Dexter (2014) explain that informal learning improves communication among teachers and provides a just-in-time support for those teachers seeking help. These participants concurred that when they engaged in informal meetings as teachers, they found themselves talking about what affected them at work, thus, providing each other with on-the-spot just-in-time professional support and learning. Jones and Dexter view the power of informal professional learning as the consideration of individuals' choices of the subject for discussion and the way those discussions occur. When these teachers met, they discussed issues of their choice relating to their practice and lives.

Social gatherings have been discussed as spaces for professional learning activities through sharing experiences and good practices, community involvement and informal meetings engaged in by FET Grade 12 mathematics teachers. These platforms of professional learning, from which learning occurred through casual discussions these teachers unconsciously engaged in, resulted in teacher learning. The next section discusses professional learning of FET Grade 12 mathematics teachers through collaboration with other schools.

Collaboration with other schools

Collaboration with other schools as professional learning spaces for the FET Grade 12 mathematics teachers explored, related to schools' interdependence which benefitted both teachers and learners. Collaboration with other schools is commitment towards interpersonal caring and support that encourages meaningful education through successful partnerships of teachers and learners (Slater 2014; Hayes 2016). Through such collaboration, school structures facilitated opportunities for colleagues to work together as they depended on each other for their own learning and work. Thus, professional learning opportunities emanated from a wide range of activities such as twinning of schools, networking and tutorials.

Twinning of schools

Twinning of schools involves exchanging students and teachers between two schools to influence the learning process for both teachers and learners. Panyaza (2015) explains twinning of schools as sharing physical, human and psychological meditational resources to help learners achieve better results. The FET Grade 12 mathematics teachers reported that twinning schools which held common values and expectations promoted and shaped their interactions and professional learning. Teacher 15 during FF Interview 3 explained their learning through twinning by reporting that:

> *I learn from twinning my school with some well-known schools in the area to encourage learning from others and make my learners appreciate that they can also manage to excel in mathematics. I learn from seeing others doing the work and observing the learning environments at other schools.*

All the 26 FET Grade 12 mathematics teachers investigated experienced professional learning through twinning from observing each other's practices. Thus, twinning promoted teacher professional learning by gleaning from each other's teaching approaches, experiences, learning environments and situations. From the theoretical framework, this relates to professional learning engaged in for occupational needs (Fraser et al. 2007) where teachers need pedagogical skills to present mathematical concepts to learners. Professional learning through twinning emerged from sharing information, resources, ideas, and expertise, working as teams and building trust, thereby making learning more accessible and effective for learners. Networking also emerged under collaboration with other schools.

Networking

24 of the 26 FET Grade 12 mathematics teachers realised professional learning through networking as a means to address challenges in their work which were difficult to tackle individually. Trust et al. (2016) views professional learning through teacher networking as founded and anchored on the notion that 'Together we are better'. These teachers reported that networking enabled them to cope with increased emphasis on continuous professional development and the demand for quality performance.

Teacher 5 during PEI showed that networking with other teachers was beneficial and enlightening. Teacher 5 explained that:

> *I learn from networking with other teachers who help me to deal with some of the challenges I meet in my work. Be it content challenges or ways of approaching certain topics when teaching. We are always in touch to support one another.*

The quotation above expresses that these FET Grade 12 mathematics teachers (24) professionally learnt from networking with other teachers as they received assistance to deal with challenges in their teaching roles. Reviewed literature (Brown 2019) shows that teachers can sustain their schools through their connection to diverse partners and networks. The networking for FET Grade 12 mathematics teachers created 'connections of practice' which addressed the interests and concerns of members.

Thus, professional learning for FET Grade 12 mathematics teachers through networking hinged around sharing advice and expertise about their challenges and work, as well as promoting creativity in their teaching roles. These teachers also experienced professional learning from tutorials.

Tutorials

Generally, tutorials are a teaching strategy whose intentions are to meet individual learner needs for specific aspects of their content. FET Grade 12 mathematics teachers (24) considered tutorials as a favourable teaching strategy which provided specific professional learning for teaching given groups of learners. Farooq (2013) views a tutorial as a teaching method which follows-up what has been learnt before, which is guided by principles of individual differences and remedial teaching of learners. Through tutorials, these teachers experienced some professional learning when other teachers conducted tutorials with their learners and when they conducted tutorials in other schools. One of these teachers explained:

> *I learn from other teachers conducting tutorials with my learners. During tutorials learners get individual attention from teachers. Sometimes I use my learners as peer tutors. I have learnt that learners participate freely in tutorials and ask questions.* (Teacher 13 during FF Interview 3)

From the response above, the FET Grade 12 mathematics teachers experienced professional learning through observing colleagues engaged in concrete tasks (Villegas-Reimers 2009) of conducting learner tutorials. Tutorials offered a one-on-one opportunity for partners in learning to converse, clarify and illustrate concepts for the parties to understand. Such opportunities for discussion created space for professional learning for FET Grade 12 mathematics teachers.

CONCLUSION

This chapter presented findings on 'how FET Grade 12 mathematics teachers engaged in professional learning through teaching roles'. The FET Grade 12 mathematics teachers indicated that they professionally learnt through in-school and out-of-school professional sites. Relating to in-school sites, these teachers experienced professional learning from professional spaces offered by classroom practice, school meetings and seminars, research, internet, use of technological sources and additional roles.

In relation to classroom practice these teachers experienced professional learning through lesson preparation, lesson delivery, assessment and feedback, remedial and extension work, classroom management and team teaching. First, during lesson preparation the teachers engaged in reading textbooks, collegial consultations and discussions, choosing teaching strategies, lesson planning, reflecting on previous lessons, watching demonstration lessons and planning together as they professionally learnt in their roles. Second, through lesson delivery, professional learning was realised through setting the scene for a lesson, interacting with learners, brainstorming concepts and use of games. Third, assessment and feedback contributed to professional learning as both teachers and learners engaged in self-introspection necessitated by results of marking and feedback, as well as detection and remedy of errors identified. Fourth, teachers engaged in remedial and extension roles from which they professionally learnt through designing remedial programmes, accommodating learners' characteristics and capabilities and providing suitable activities for diverse learners.

Fifth, classroom management provided professional learning experiences through creating a conducive learning environment, enforcing classroom rules, sharing experiences with other teachers and maintaining a good working rapport with learners. Sixth, about team teaching, the FET mathematics teachers engaged in professional learning through observing colleagues teaching, interacting with learners, dealing with learners' questions and creating a suitable learning environment.

With regard to school meetings and seminars teachers experienced professional learning through departmental meetings and seminars and whole school meetings. Professional learning for these teachers was realised through participation and facilitation in the scheduled meetings and seminars. In the departmental meetings and seminars, FET Grade 12 mathematics teachers engaged in content gap learning and sharing teaching strategies for specific topics to equip them for their lessons. In whole school meetings the teachers learnt professionalism, professional ethics and interdependence.

Research also offered professional learning for FET Grade 12 mathematics teachers as they perused the internet, read widely, learnt new content and discovered new methods and strategies for teaching. They also learnt from research done by their learners which was shared. From the use of technological resources, mathematics teachers realised professional learning through materials accessed from other teachers and organisations and reading e-books on the internet. Professional learning was further experienced from technological resources through watching exemplary lessons on television and engaging in collaborative reflections. The teachers also experienced their learning through the use of technological equipment such as the whiteboard and computer for power point presentation. These teachers realised professional learning through their application of technological skills such as accessing, downloading and printing information from on-line social networking. The knowledge of manipulating technological resources for their benefit encouraged these teachers to professionally learn from technological sources.

With respect to additional roles, FET Grade 12 mathematics teachers engaged in professional learning through co-curricular activities, administrative roles, learner support and conducting school assemblies. From co-curricular activities these teachers professionally learnt through participating in coaching, communicating with learners and reflecting on observable learner attributes. Regarding administrative roles, professional learning occurred through maintaining discipline and participating in decision making. On the other hand, learner support offered professional learning through rapport with learners, improving learner access to information and providing guidance to learners. From conducting assembly, the teachers also professionally learnt through conducting devotions, preparing learners for learning and giving social and moral guidance to learners which is important for effective learning.

With respect to wide professional sites, professional learning manifested through workshops, social gatherings and collaboration with other schools. Regarding workshops, professional learning was experienced through cluster, district and provincial workshops. Cluster workshops involved joint planning meetings, marking of tests and examinations and task moderations, from which the FET Grade 12 mathematics teachers experienced professional learning. District and provincial workshops also provided professional learning through discussions on curriculum changes, policy changes and content gaps.

Social gatherings involved sharing experiences and good practices, community involvement and informal collegial meetings. The FET Grade 12 mathematics teachers engaged in professional learning discussing workplace challenges, seeking advice and attending community gatherings and functions, games and ceremonies.

Professional learning for FET Grade 12 mathematics teachers was also realised through twinning of schools, networking and tutorials. Twinning of schools offered professional learning through working as teams, sharing and building trust of each other. In the case of networking, professional learning occurred through sharing advice, expertise and creativity, while tutorials offered professional learning through conducting tutorials, participating in discussions and creating an open environment for learning.

Having presented data and findings that addressed how FET Grade 12 mathematics teachers engaged in professional learning through teaching roles, the next chapter presents and analyses data on the second research question regarding the kinds of professional knowledge that the FET Grade 12 mathematics teachers gained from their professional learning within their teaching roles.

CHAPTER FIVE

DATA PRESENTATION AND ANALYSIS: KINDS OF PROFESSIONAL KNOWLEDGE FET GRADE 12 MATHEMATICS TEACHERS GAIN THROUGH TEACHING ROLES

Introduction

The study sought to establish professional learning of FET mathematics teachers through teaching roles and how it influences their pedagogical practices. The previous chapter presented and analysed data for the first research question addressing how FET mathematics teachers engaged in professional learning through their teaching roles. This chapter, the second data presentation and analysis chapter, addresses the second research question: *What kinds of professional knowledge do the (FET Grade 12 mathematics) teachers gain* from their professional learning in their teaching roles.

The data addressing this question was generated through four focus group discussions (FGDs), thirty-two individual face-to-face interviews (FF Interviews) and sixteen photo-elicitation interviews (PEI). As detailed in the methodology chapter, the photographs that participants took were only used to prompt discussion: they are not and were not meant to be displayed in the thesis, to uphold participant anonymity and confidentiality.

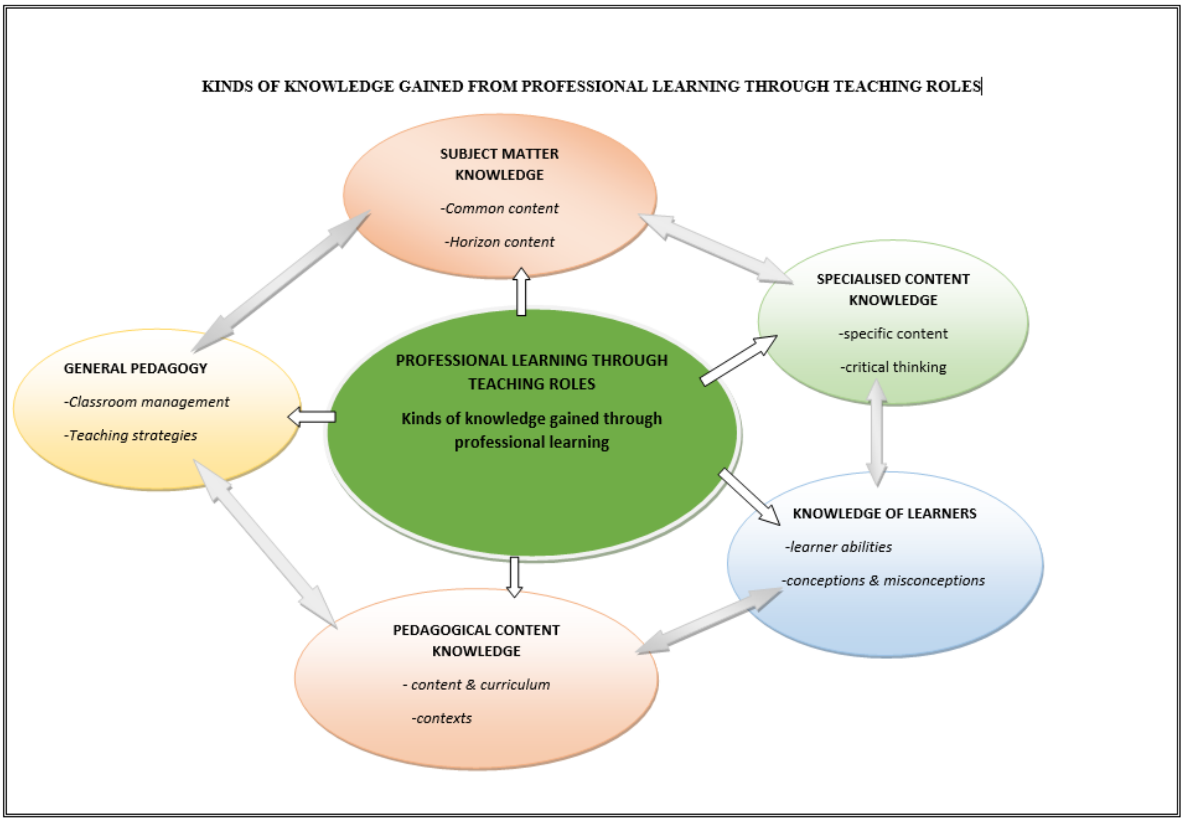
In presenting and analysing the data, I draw on related literature reviewed in Chapter Two to illustrate whether or not the findings in this study support or contradict existing research. I also draw on the domains of professional knowledge as propounded by Ball, Thames and Phelps's (2008) Mathematical knowledge for teaching (MKT). I incorporate domains of knowledge as proposed by Cogill (2008), Hill et al. (2008) and Hurrell (2013) to complement Ball et al.'s theoretical framework.

As alluded to in the theoretical framework section, Ball et al.'s (2008) MKT, a practice-based theory, provides profession-specific knowledge for mathematics teachers and proposes that mathematics teaching requires specific professional knowledge of subject matter and pedagogical content knowledge. Subject matter knowledge exists as common content knowledge, knowledge at the mathematical horizon and specialised content knowledge while pedagogical content knowledge is composed of knowledge of content and students, knowledge of content and teaching and knowledge of content and curriculum (Hill et al. 2008; Hurrell 2013; Speer et al. 2015). Ball et al. (2008) acknowledge that mathematics teachers also require knowledge of contexts.

Themes and sub-themes

Broadly, in answer to the kinds of professional knowledge that FET Grade 12 mathematics teachers professionally gained, findings revealed five themes: subject matter knowledge (SMK); specialised content knowledge (SCK); general pedagogical knowledge (GPK); pedagogical content knowledge (PCK); and knowledge of learners (KOL) reflected in Figure 5.1 These themes frame the chapter and are discussed in turn.

Figure 5.1: ***Kinds of knowledge gained from professional learning through teaching roles***



Source: Researcher (2021)

In Figure 5.1, the arrows linking the different kinds of knowledge show that during instruction these kinds of knowledge are integrated, and influence each other to enhance teacher competence. Before the discussion, responses from the teachers about the different kinds of professional knowledge gained are illustrated in Table 5.1 below.

Table 5.1: Number of teachers who indicated kinds of knowledge they professionally gained per theme

	Thematic responses on kinds of knowledge gained through professional learning									
Sub-Themes	Common content	Horizon maths	Specific content	Critical thinking	Classroom management	Teaching strategies	Learning contexts	Content & curriculum	Learner abilities	Learner conceptions
Totals	**26**	**14**	**23**	**13**	**12**	**26**	**18**	**23**	**20**	**26**

Source: Researcher 2021)

Table 5.1 above shows that all the 26 teachers in this study gained professional knowledge related to common content knowledge, knowledge of teaching strategies and learner conceptions, while 23 of them gained specific content and content and curriculum. Twenty and fewer teachers gained knowledge related to the other sub-themes shown in the table. Each theme is discussed, and summarised through its sub-themes. Subsequently, a conclusion ties the paper together. Subject matter knowledge that the FET Grade 12 mathematics teachers gained is discussed first.

Subject matter knowledge

Findings revealed that all the teachers gained subject matter knowledge (SMK). SMK is understood as the knowledge in a subject encompassing what teachers teach and what is not directly linked to the concepts being taught in the classroom (Cogill 2008; Switzer 2015). The MKT theory (Ball et al. 2008) considers SMK as the knowledge that includes the content of the subject and its organising structures. Ball et al., supported by Hurrell (2013) and Shulman (1987), recognise SMK as designed around the notion that knowing a subject for teaching demands more than knowing its facts and concepts. Hence, SMK which emerged in this study and also in MKT (Ball et al. 2008) is categorised into three subdomains to cater for the various teaching knowledges involved: common content knowledge; knowledge at the mathematical horizon; and specialised content knowledge. However, specialised content knowledge will be discussed as a separate theme due to the emphasis accorded to it in the findings. The subsequent section discusses common content knowledge FET Grade 12 mathematics teachers gained in their teaching roles.

Common content knowledge

As highlighted above, 26 FET Grade 12 mathematics teachers gained common content knowledge from their professional learning through teaching roles. Ball et al. (2008) interpret the word "common" as not implying the knowledge can be acquired by everyone or that it is easy to get but that it is a type of knowledge that is widely used in different settings. Thus, common content knowledge is explained as the mathematical knowledge and skill widely used in general settings which is not necessarily unique to teaching but also encompasses questions that can easily be answered by other people who are not necessarily teachers but know some mathematics (Ball et al. 2008). This domain of knowledge is often known as the knowledge of mathematics that promotes mathematical operations in life, such as distinguishing between shapes, calculating annuities, calculating discounts, change and profits, appreciating statistics and probabilities in different settings. This knowledge, however, is also profession-specific insofar as mathematics teachers need to know the content they teach, distinguish between correct and incorrect answers, recognise inaccuracies in textbooks and use mathematical terms and notation accurately (Ball et al. 2008; Shulman 1987) for effective execution of their instructional roles.

Teacher 13 during FF Interview 3 explained that: "*I learnt content about two-and-three-dimensional shapes, sequences, functions and different types of equations which was not familiar to me but helpful in my life and career".* Similarly, Teacher 3 in FGD 4 reported that: *"I learnt content about sequences and how to discover number patterns and derive formulae."* The response by Teacher 13 shows that some FET Grade 12 mathematics teachers professionally gained common content knowledge about topics they teach in their curriculum. The content gained was helpful for these teachers in their instructional roles. The responses suggest that knowledge about these topics gave them wider knowledge about facts and concepts which were vital to their teaching roles. The knowledge of facts and concepts enriched the mathematics teachers in line with the conceptual framework (Cogill 2008) that when teachers have more content, they teach better and when they lack content, they circumvent those aspects of the content they do not know. Teacher 3 added that the mathematical content that they gained through their teaching roles helped them to discover patterns and derive formulae useful in their teaching roles. Formulae are usually regarded as generalisations that are reliable for calculating solutions to mathematical problems of a related nature. They are generally driven from a close analysis of patterns that arise in solving mathematical problems of a related nature. Drawing from theory (Ball et al. 2008) MKT encourages mathematics teachers to identify mathematical patterns and make useful generalisations in their roles which is what Teacher 3 is talking about. Kretchmar et al. (2016) and Rollnick and Mavhunga (2015) emphasise that teachers should acquire adequate common content knowledge to be able to effectively pass it on to others.

The FET mathematics teachers also indicated that they gained common content knowledge as Teacher 7 in a PEI reported: "*I learnt how to construct solid shapes using sticks and paper. … and I learnt content knowledge about the properties of the solid shapes*." Teacher 7 was engaged in practical activities of making solid shapes out of sticks and paper from which they learnt content about the properties of these shapes. Common content knowledge about constructing solid shapes helped these teachers to understand the shapes and their properties, that is, the number of sides, corners and edges, hence, professional learning through teaching roles. Common content knowledge gained in this regard encouraged learning by doing. Informed by theory (Ball et al. 2008 and Shulman 1987) these teachers were organising content knowledge in their minds about their subject. The FET curriculum has a topic on measurement where they would calculate surface area and volume of plane and solid shapes and common content knowledge about these shapes would be indispensable. Consulted literature (Heggart 2016; Zeichner 2016; Wineburg 2015) emphasises the importance of this kind of knowledge for teachers as this is the material that they teach. These researchers propose a high proportion of SMK in the form of common content knowledge in the education and training curriculum for this reason. Drawing from theory (Ball et al. 2008) mathematics teachers' knowledge of content should always be far more than that which they teach their learners. In this regard, teachers are then able to detect the various forms of instructional challenges faced by their learners without pressure in their teaching roles.

Further, Teacher 5 during FGD 3 commented: *"I learnt mathematical content about statistics and probability and their application in growth and development in our lives."* Statistics and probability which were professionally learnt were topics in the FET syllabus. They are generally widely used to interpret data and make conclusions about social phenomena like drought, disasters, success and failure. For FET Grade 12 mathematics teachers, the wide use of statistics and probability in describing events provided professional learning knowledge effective for their teaching roles. Conceptual frameworks (Hurrell 2013 and Hill et al. 2008) suggest that common content knowledge is vital for use in settings other than teaching. Drawing on theory (Ball et al. 2008) those who know and use mathematics daily, apply common content knowledge as a language for describing situations and circumstances in their environment, hence, common content knowledge is used in various settings.

In the discussion above, through their teaching roles, FET Grade 12 mathematics teachers professionally gained common content knowledge related to shapes, sequences, functions, equations and constructions, as well as statistics and probability and their application in different settings. Therefore, common content knowledge is integral mathematical knowledge where teachers understand the organising principles, structures and rules regarding the content they teach. The FET Grade 12 mathematics teachers in their teaching roles also professionally gained knowledge of mathematics at the mathematical horizon which is discussed below.

Knowledge at the mathematical horizon

14 FET Grade 12 mathematics teachers through their teaching roles also professionally gained knowledge at the mathematical horizon. Related literature (Switzer 2015) defines knowledge at the mathematical horizon as mathematical knowledge that links topics at a particular grade level to the preceding and subsequent grade level. Generally, the mathematical link from one grade to another is vertical curriculum alignment which is paramount for mathematics teaching where concepts build one over another in a chronological order. Ball and Bass (2009) conceive knowledge at the mathematical horizon as knowledge which involves how mathematics used in instruction relates to the wider mathematical environment. From the two definitions, knowledge at the mathematical horizon is more than just curriculum interrelatedness but also includes how mathematics is located in and linked to the broader mathematical territory. In this study, knowledge at the mathematical horizon was generally understood as knowledge of sequencing and linking of topics, as well as their integration across subjects which enhanced the relatedness of mathematical ideas. Drawing from theory (Ball et al. 2008), other than the vertical curriculum, knowledge at the mathematical horizon is attached to knowledge of the horizontal curriculum which relates to the association of concepts within the same grade level and/or association of mathematics with other disciplines. For example, the knowledge of functions progresses from one grade to the next in hierarchical (vertical) order to enhance coherence. Again, functions relate to processes in industry where inputs pass through a process to give outputs/products, just like in a function where the values of (x) substituted in a function will yield the values of (y). Thus, knowledge at the mathematical horizon is important to teachers as they prepare for

instruction so that their instruction focuses on intended outcomes for learning ahead and contribute to applied contexts of mathematical concepts.

Knowledge at the mathematical horizon professionally learnt by FET teachers was exemplified by Teacher11during FF Interview 3 who explained that: *"I learnt what learners learnt from previous grades and what I need to teach. I also learnt the content for the next grade".* Teacher 11 above, gained knowledge of content learnt, content to be learnt and content for subsequent grades from reading curriculum documents and through collegial discussions. This was knowledge at the mathematical horizon in the form of knowledge of the vertical curriculum. Informed by theory (Ball et al. 2008) and conceptual frameworks (Hurrell 2013 and Hill et al. 2008), knowing the vertical curriculum empowers teachers in their roles to make connections across the topics in mathematics for different grades. This is consistent with the ideas of consulted literature (Jacobsen 2013) that knowledge at the mathematical horizon involves a sense of how elementary mathematics taught leads to advanced mathematics.

Drawing on the theoretical framework (Hurrell 2013), knowledge at the mathematical horizon is what teachers require to link the thinking of their learners to the fundamental ideas and application of mathematics. Literature surveyed (Jacobsen 2013) also perceives this domain of MKT as what links the mathematics used in teaching and its application in life. Knowledge at the mathematical horizon which FET Grade 12 mathematics teachers professionally gained transcended grade levels. The FET mathematics teachers also professionally gained knowledge about the application of mathematics in some careers during learners' career guidance. Teacher 5 during FGD 4 confirmed that: *"I learnt how mathematics is applied in careers such as engineering, mining and medicine. As a mathematics teacher my understanding of these career choices helped me to learn to focus my teaching and give relevant examples during instruction."* FET Grade 12 mathematics Teacher 5 professionally gained the knowledge that depicted the kind of mathematical content that is applied, as well as areas to focus on which would probably help their learners to secure jobs in the fields of engineering, mining and medicine. This is likely to have provided the impetus for these teachers to work even harder to support their learners and equip them appropriately for such careers. The application of mathematics in different careers is supported by researchers (Heggart 2016; Wineburg 2015) who consider knowledge at the mathematical horizon as characterised by the ability to hear students' ideas in order to direct instructional practices. In this regard, a conceptual framework (Hill et al. 2012) confirms knowledge at the mathematical horizon as essential for motivating mathematics teachers towards instructional quality.

The FET Grade 12 mathematics teachers also gained knowledge at the mathematical horizon as they discussed their experiences with colleagues. Exposure to the application of mathematics in life, made mathematics a practical subject applicable in different scenarios. Teacher 14 in FF Interview 3 shared the following experiences: *"I learnt … to appreciate the value of maths in everyday life. … I learnt to calculate the rate of inflation."* Supporting the same idea during FGD 2 Teacher 5 confirmed that: *"We usually discuss about items on discount and calculate how much we can save by buying the items on discount."* These teachers gained knowledge at the mathematical horizon about buying and selling related to financial mathematics which was a topic in the syllabus. However, there were no responses that referred to knowledge at the mathematical horizon reported during PEIs. Probably this was because discussions in this category of data generation depended on participants choices of activities that were photographed. However, aligned to theory (Ball et al. 2008), knowledge at the mathematical horizon gained from the use of mathematics in life and affirmed that teachers must be able to articulate how the mathematics they teach would fit into the mathematics of the later world.

The discussion above revealed that knowledge at the mathematical horizon professionally gained by FET Grade 12 mathematics teachers through teaching roles related to knowledge of vertical and lateral curricula, knowledge of mathematical application in different careers and knowledge of the practical use of mathematics. This knowledge at the mathematical horizon enabled these teachers to make mathematical connections of the mathematics which they teach with the world of work and their daily living. The following section discusses specialised content knowledge.

Specialised content knowledge

Specialised content knowledge (SCK) was another form of knowledge professionally gained by FET mathematics teachers through teaching roles. Ball et al. (2008), Hurrell (2013) and Dreher (2018) share the same definition that SCK is the knowledge and skills of mathematics teaching unique to teaching this subject. Research (Hill et al. 2013) presupposes that effective mathematics teachers possess unique knowledge of their learners' mathematical ideas and thinking. Drawing on theory (Ball et al. 2008), SCK is the MKT domain which recognises preconceptions and background knowledge that learners bring to their learning and is founded on observations of how then teachers technically explore the content for teaching. Similarly, Hill et al. (2008) further note that SCK embraces the manner in which teachers accurately provide explanations to common mathematical rules and procedures, represent mathematical ideas, examine and understand unfamiliar answers to problems which Grossman (1990) terms "psychologising" content. SCK is the part of subject matter knowledge which shifts mathematics teaching from a casual nature to a professional one where mathematics teachers know the subject matter in a qualitatively different way from other users of mathematics (Scheiner et al. 2017). In this study, specialised content knowledge, which was professionally gained by FET mathematics teachers in their teaching roles was generally considered as the knowledge and skills of mathematics needed for teaching, based on trends of thought processes of learners at particular grade levels. SCK is analysed and discussed through sub-themes: knowledge for specific content and knowledge related to critical thinking and problem-solving.

Knowledge of specific content

The knowledge of specific content generally relates to the knowledge professionally gained by 23 FET Grade 12 mathematics teachers which is specific to their teaching roles and may not be relevant to other settings. Informed by theory (Ball et al. 2008), this is knowledge the teachers would acquire to be able to understand the topics beyond the learners' level which would make them profession-specific in their roles. Surveyed literature (Carrillo 2013) notes that through the knowledge of specific content, privy to their learners' situations and circumstances, the teachers would ask themselves how well they could get their learners to understand a particular concept.

Drawing from theory (Ball et al. 2008) and conceptual framework (Hill et al. 2008), mathematics teachers who have professionally gained knowledge of specific content know mathematics and mathematics teaching beyond ordinary mathematical representations. They are often crafty and can demonstrate mathematical concepts explicitly to learners. To allude to this view, Teacher 16 during FF Interview 1 said: "*We learnt specific mathematical concepts that we teach in Grade 12 like factorisation of quadratics, differentiation and trigonometry and I also learnt new ways of approaching them for teaching."* The knowledge of different content taught to Grade 12 professionally gained through teaching roles seemingly contributed unique mathematical understanding and reasoning. Teacher 16 learnt how they could specifically teach the topics that they learnt to their learners which confirms theory (Ball et al. 2008) that teachers who possess knowledge of specific content should be able to know mathematics content beyond what is needed by learners. Learning other ways of approaching the content for teaching is also consistent with theory (Ball et al. 2008) regarding knowledge of specific content. The mathematical demands for teaching need specialised mathematical knowledge which is not required in other settings. Thus, learning mathematical content and how it must be presented to learners for better understanding distinguishes mathematics teachers from those of other disciplines. This is consistent with theory (Bell and Gilbert 2005) which perceives knowledge of specific content as specialised teacher knowledge and skill peculiar to their occupational domain of influence.

Teacher 3 during FF Interview 1 added that: *"I learnt how to identify common errors learners make in different topics … and also learnt different ways I could avoid them as I teach."* This FET mathematics teacher professionally gained knowledge of specific content in the form of identifying common errors in learners' work. Identifying common errors in learners' work is in line with theory (Ball et al. 2008) which urges teachers to look for patterns in learners' errors in their instructional roles. Usually, common errors depict learners thinking about an idea which basically informs the teachers about their instructional processes. Consulted literature (Carrillo 2013; Ball and Bass 2008; Jacobsen 2013; Speer et al. 2015) encourages mathematics teachers to interpret mathematical work produced by learners to get insight into new approaches for teaching. Generally, there is good retention of professional knowledge gained from identification of errors and such knowledge tends to refine teachers' knowledge of specific content. This is consistent with the conceptual framework (Cogill 2008) which encourages teachers to help learners with difficulties. While identification of learners' errors can be done by other people in other settings, doing it for purposes of helping learners understand their learning in mathematics is peculiar to teaching.

Further, Teacher 7 during PEI explained that FET teachers professionally gained knowledge of preparing for teaching specific topics saying: "*I learnt how to plan for teaching specific topics, breaking down content by identifying the major aspects of the topics and areas of emphasis for teaching."* Teacher 7 above professionally gained knowledge of specific content around planning for specific topics to ensure effective teaching and learning. The knowledge gained of planning for specific topics, identifying key aspects of the topic and identifying major areas of emphasis for teaching is aligned to theory (Ball et al. 2008) which proposes that teachers must unpack mathematical knowledge into teachable units. This is unpacking of content which is exclusively the work of a teacher where content is broken down into small teachable units with special reference to the ambit of the learners. Knowledge of specific content professionally gained in the form of planning for specific topics seems to have the benefit of sizing up and figuring out (Scheiner et al. 2017) how content must be chosen to best fit the understanding level of learners and that is unique to teachers. In line with this, conceptual framework (Cogill 2008) reiterates that teachers must present work in a way favourable to learners. Thus, knowledge of specific content seemingly provided these teachers with specialised mathematical knowledge and skill particularly for teaching mathematics.

Explaining the importance of the knowledge of specific content further, Teacher 2 during FF Interview 3 reported:

> *I also learnt how to introduce and develop concepts working out examples in topics such as Euclidean Geometry, Optimization in differential Calculus and to some extent the Counting Principle. From these topics I learnt how to explain concepts and justify answers to questions for others by giving reasons for statements made which gave me confidence in my teaching.*

The FET Grade 12 mathematics teachers professionally gained knowledge of introducing and developing concepts in highlighted new and threatening topics. Usually, lessons either succeed or fail at the introduction stage as an effective introduction often captures learners' attention and develops their zeal to learn. Informed by conceptual framework (Cogill 2008) teachers must manage lesson introductions to stimulate learners for learning. Teachers also learnt how to develop concepts by working out mathematics examples in the topics identified. Further, they learnt how to explain their solutions to others giving reasons for statements made to justify the answers. This is aligned to theory (Ball et al. 2008) and consulted literature (Carrillo et al. 2013) where the knowledge of specific content is the route to answering learners' mathematical 'why' questions. Generally, concept development entails coming up with a detailed description of a mathematical idea tailored to the perspective of the learner. There are two things in concept development that a teacher has to familiarise him/herself with to deliver concepts effectively. Firstly, the teacher must know the facets which together build into the concept. Secondly, the teacher must understand the learner who should know the concept. Thus, knowledge of these two factors would be exploited to design a procedure towards concept development. Taken together, these two factors are specialised work the mathematics teacher would need to develop a concept and this is peculiar to teaching. This is a principle for knowledge of specific content alluded to by theory (Ball et al. 2008: 400) as “choosing and developing useable definitions and modifying tasks to be either easier or harder.” Informed by conceptual framework (Hill et al. 2008), mathematics teachers must represent mathematical ideas and provide mathematical explanations for common rules and procedures accurately in their roles.

In the discussion above, the FET mathematics teachers through their teaching roles professionally gained knowledge of specific mathematical concepts, related to common errors learners made in different topics, planned for specific topics and identified major aspects of topics for emphasis during lesson delivery. They also professionally gained content knowledge of new topics in the curriculum and how to develop concepts in those topics. This was SCK in the form of knowledge of specific content professionally gained by these teachers. It emerged that through teaching roles these teachers professionally gained confidence in teaching and widened their scope of relevant content. The following section discusses critical thinking and problem solving.

Critical thinking and problem-solving

FET mathematics teachers (13) also professionally gained specialised content knowledge related to critical thinking and problem-solving as they dealt with mathematical problems during instruction. Usually, critical thinking is referred to as careful thinking directed to a goal. However, consulted literature (Doyle 2019) conceives critical thinking as the intellectual process of actively and carefully conceptualising, applying, analysing, synthesising and evaluating information gathered or generated by observation, experience, reflection, reasoning or communication in problem-solving. In line with theory (Ball et al. 2008) mathematics teachers, through SCK, are expected to analyse and select textbooks and from time to time make judgements regarding learners work where critical thinking is a necessity. Hence, critical thinking will be viewed in this study as the ability to think clearly, carefully and rationally, looking at pros and cons and understanding the logical connections between ideas for decision-making and problem-solving.

Surveyed literature (Nieuwoudt and Golightly 2006) urges that mathematics teachers are responsible for the development of critical thinking skills in order to achieve pedagogical outcomes. Elaborating about critical thinking Teacher 1in FGD 2 explained that:

I learnt to develop critical thinking skills in the teaching of mathematics story problems; to guide and give clues to the learner to think out of the box in order to solve some mathematical problems on their own. I also discovered new methods of teaching from the effort of learners. (Teacher 1in FGD 2)

Teacher 1 professionally gained knowledge related to developing critical thinking and problem-solving skills as special knowledge in their teaching roles. Reviewed literature (Firdaus et al. 2015: 227) defines development of critical thinking skills as creating "analytical thinking and reflection that involves testing activities, questioning, connecting and evaluating all aspects of a … problem." The knowledge of developing critical thinking in mathematical problem-solving is an important aspect for most mathematics teachers. Mathematics teachers are generally always concerned about their ability to critically think and solve mathematical problems themselves as they often face challenges to transfer the same knowledge to learners. Thus, the knowledge related to developing critical thinking skills professionally gained by some FET Grade 12 mathematics teachers seemingly equipped them with some techniques to in turn develop their learners' critical thinking skills. This is consistent with theory (Ball et al. 2008) where teachers are encouraged to build learners' mathematical ideas by promoting learners' thinking and provoking divergent thoughts which would probably help learners manipulate existing knowledge and information to obtain solutions to new problems. The teacher also gained knowledge related to guiding and giving clues to learners 'to think out of the box' as knowledge specific to critical thinking and problem-solving in teaching mathematics. Through probing, 'thinking out of the box' meant providing small doses of advice to guide learners to think independently and widely by connecting the dots for problem-solving. In this regard, 'thinking out of the box' emanates from guiding learners in their learning. Guiding learners is a major role for teacher pedagogical practice which promotes effective learning and higher learner achievement. This is aligned to conceptual framework (Cogill 2008) that teachers should provide conditions so that learners understand the work that they do. Promoting ideas of critical thinking by guiding and giving clues, constructivist theories (Vygotsky 1978; Piaget 1978; Narayan 2011) stress that teachers as facilitators should structure the learning experiences in such a way that they give clear guidance and parameters within which learners can discover their own solutions to learning problems. Hence, critical thinking skills professionally gained were likely to be part of their learners' learning which they would direct as teachers in their roles.

Some of the participants from other data generation sources concurred as they explained that they often use story problems to teach critical thinking in their teaching roles. Teacher 8 in FF Interview 3 reported that: "*I learnt critical thinking and problem-solving by analysing mathematical story problems and puzzles*." Teacher 10 during PEI in support of the same sentiments explained that: *"I learnt critical thinking and problem-solving as I identified key words in a story problem and make use of them to get my solutions."* Teacher 8 and Teacher 10 professionally gained the knowledge of critical thinking related to analysing mathematical story problems and identifying key words in a story problem respectively. Generally, a mathematical story problem is a mathematical problem presented as a narrative, not written in mathematical notation, showing a scenario which requires a mathematical calculation to solve. Key words were usually terms in a mathematical sentence which carried ideas that led one's thinking towards a desired solution. It is through analysis of story problems by examining key words that Teacher 8 and Teacher 10 professionally gained critical thinking and problem-solving skills. Thus, story problems are usually fertile ground for teaching critical thinking as they require reasoning to understand terms and identify clues which when put together represent the dots that must be connected to give a solution (Zorfass and Gray 2014). Critical thinking is usually a liberating tool for problem-solving through analysis and synthesis of scenarios in mathematics and life in general, as highlighted by Teacher 10 who in turn professionally learnt to use the skills learnt to arrive at solutions. Research by Vargas (2012) established that knowledge of critical thinking and problem-solving for mathematics teachers is beneficial to their teaching roles insofar as it coordinates related concepts and promotes open thinking. Vargas further indicates that knowledge of critical thinking and problem-solving for mathematics teachers in their teaching roles includes development of checklists to judge and create new ideas which are then used to solve mathematical problems.

Teacher 12 during PEIs added that: *"I also learnt that during problem-solving I should listen to learners' arguments and it is important to take learners step by step reading the question while acting on the instructions."* From the response, knowledge of critical thinking and problem-solving was also professionally gained by the FET Grade 12 mathematics teacher as they learnt to listen to their learners' arguments. Informed by theory (Ball et al. 2008), such arguments learners made during discussions of story problems exposed how the learners thought and, hence, gave insight for directing or re-directing learners' thoughts which enhanced critical thinking. Reports indicated that careful listening to the learners' arguments offered teachers knowledge of some strategy for understanding the learners' ideas in critical thinking which contributed to problem-solving. The teachers also professionally gained knowledge of critical thinking and problem-solving related to taking learners step by step in dealing with their mathematical problems. This is consistent with conceptual framework (Cogill 2008) which considers managing question and answer sessions during instruction as a major quality for good teaching. Seemingly, taking learners step by step exposes hidden facts in story problems and promotes critical thinking which probably leads to problem-solving. Drawing from theory (Ball et al. 2008), critical thinking and problem-solving is specialised content knowledge that informs and transforms mathematics teachers into expert professionals.

Through their teaching roles, some FET teachers concurred that they learnt some ways that could be used in guiding critical thinking among learners. Teacher 6 in FGD 2 explained: "*I learnt processes of underlining key words and phrases in the questions and asking leading questions that encourage thinking to take place."* Teacher 7 in FF Interview 3 added that: *"I learnt that when I read mathematical story problems, I should identify keys words and underline them with my learners to lead them to think critically."* Identification of key words and phrases in story problems professionally gained by these FET teachers often promotes critical reasoning and focuses thinking for purposes of problem-solving. The knowledge of and practice of underlining key words helps to ensure that the key concepts are interpreted and addressed. Informed by theory (Ball et al. 2008) mathematics teachers require understanding of mathematical interpretations of operations in qualitatively different ways more than their learners to deal with problem-solving. These teachers also professionally gained knowledge of asking leading questions through teaching roles which complemented the knowledge of identifying key words and phrases. Mukeredzi (2019) advises that asking questions during instruction promotes intense information processing and knowledge integration which is vital in critical thinking. These teachers made reference to Euclidean Geometry questions where, for any given problem, statements of answers were always complemented by a reason. For these FET teachers giving a reason demonstrated the application of critical thinking. Surveyed literature (Alcantara and Basca 2017) in support concluded that the benefit of knowledge of critical thinking and problem-solving among mathematics teachers increases learner achievements.

The knowledge of critical thinking and problem-solving professionally gained by FET Grade 12 mathematics teachers through teaching roles was realised in various forms. These teachers gained knowledge related to developing critical thinking skills, guiding and giving clues to direct learners thinking. The knowledge of critical thinking and problem-solving that they gained related to analysing mathematical story problems, identifying key words and phrases and asking leading questions towards problem-solving. Such is specialised knowledge exclusively for mathematics teachers in their roles. The following section discusses GPK professionally gained by FET Grade 12 mathematics teachers.

Knowledge of general pedagogy

All the FET Grade 12 mathematics teachers (26) professionally gained the knowledge of general pedagogy related to classroom management and teaching strategies in their teaching roles. The MKT theory (Ball et al. 2008) used in this study disregards GPK, as it does not feature anywhere in its model. Consequently, discussion of this knowledge domain will be informed by Cogill (2008), Grossman (1990) and Shulman (1987). Drawing from Shulman (1987), GPK is the functional knowledge that relates to the principles and strategies of classroom management and organisation which promotes teaching and learning in the classroom. Reviewed literature (Francis, 2018) perceives it as the special knowledge for teachers vital for effective facilitation of student learning and the creation of conducive learning environments. In this study, GPK is regarded as teacher knowledge related to the manipulation of teaching strategies and the environment in facilitating student learning and classroom practice. Some proponents of teacher knowledge (Shulman 1987; Cogill 2008; Guerriero, 2017) assert that GPK is based on the premise that learning takes place in a social context and the performance of learners depends on the quality of the teacher and factors influencing their learning environment. The GPK professionally gained by FET Grade 12 mathematics teachers through teaching roles is discussed and analysed through its sub-themes: knowledge of classroom management and knowledge of teaching strategies.

Pedagogical Knowledge related to classroom management

From their professional learning, all FET Grade 12 mathematics teachers (26) gained GPK related to classroom management. Such knowledge of classroom management entails the understanding of all activities and situations that prevail in and enhance the teaching process. These teachers professionally gained knowledge of managing and controlling the class while maintaining focus on the teaching process. Thus, the GPK of classroom management is generally regarded as the ‘how to’ or ‘practical knowledge’ (Cogill 2008; Grossman 1990) necessary to manage and control the teaching and learning process. Teacher 21 in FGD 4 explained this and said:

I learnt that I don't have to work behind the pace setter. Every time I must be ahead of the pace setter so that I am able to get time for revision for June and Trial examinations. I also learnt ways of keeping order in the classroom.

Teacher 7 during FF Interview 3 added that:

I learnt how to follow my pace setter in my teaching and try to be always ahead of time to make time for revision at the end. I also learnt that how I sit learners is a disciplinary measure.

Reports by Teacher 21 and Teacher 7 above show that FET Grade 12 mathematics teachers during FGDs, FF Interviews and PEIs, professionally gained GPK about the management of time and classroom events guided by their pace setters. Time is usually a scarce resource which mathematics teachers must always manage and use effectively since once lost it is never restored. A pace setter is generally a designed programme showing what has to be taught and when, which must be accomplished in order to give all the content in the syllabus adequate attention. However, while the pace setter aids completion of stipulated instructional tasks, it may not promote deep learner understanding of concepts as teachers tend to hurriedly cover content, only at the surface, to keep within time schedules. Time management is vital for maintenance of appropriate pace with lessons and work schedules. Consequently, hurrying to finish the syllabus generally undermines the major purpose of the teaching process which is to promote quality learning and improve learner performance. Drawing from conceptual framework (Cogill 2008), through GPK teachers should maximise instructional time, pick a steady pace and maintain a clear direction during lessons. Also, teaching focussing on examinations raised in the quotes above suggests that these teachers always worked under pressure of examinations. While it is a good idea to have learners achieve well in their examinations, such focus tends to frustrate quality teaching intended in the South African curriculum. However, drawing from norms and standards for South African educators (DBE 2017), the teacher is an interpreter and designer of learning programmes in the classroom. Time management is emphasised by surveyed literature (Ugwulashi 2013) as an indispensable element for teachers to successfully accomplish their activities.

Another aspect of GPK raised in responses above that the FET teachers professionally gained in their teaching roles was maintaining discipline through organising sitting arrangements in their classrooms. These are decisions teachers made in line with conceptual framework (Cogill 2008), that one of the principles of GPK is managing and organising classroom events. Consulted literature (Guyana 2015) perceives classroom discipline as a strategy that teachers in their teaching roles use to manage student attitudes and behaviours during learning. It appears that classroom discipline and control are integral features for effective learning which helped these teachers to have their learners focus on their learning and enabled them to teach without interruptions. Sitting arrangements are generally strategically set to ensure learners accessibility to the learning facilities such as the teacher and chalkboard during instruction. Thus, classroom discipline is aligned to conceptual framework (Grossman 1990) that GPK helps to create a conducive teaching and learning environment in the classroom.

Some of the FET Grade 12 mathematics teachers who held posts of responsibility as Heads of Departments and senior teachers also gained pedagogical knowledge related to school and personnel management in those roles. Teacher 6 during FGD 1 commented that: *"I learnt how to lead other teachers and learners and carry out other administrative duties …. I learnt that I must lead by example in everything as a teacher in the class.*" Teacher 1 during PEI also explained that: *"I learnt how … to interpret school policies and manage my classroom. I also gained the strategies to manage and supervise teachers."* FET mathematics teachers (12) professionally gained GPK related to school and personnel management. The teachers professionally gained leadership knowledge for leading other teachers and learners and carrying out administrative duties. This is consistent with the South African Norms and Standards for Educators (National Education Policy Act 2019) which portrays a teacher as a leader, manager and administrator. Thus, the teachers were leaders and administrators in their classrooms, hence, the knowledge of leadership and administration was consistent with these teachers' roles. Teacher 1 identified interpretation of policies as GPK gained which empowered the teacher to confidently execute their duties in the classroom. Such knowledge appears to have given them power and authority to influence the behaviour of learners and other teachers in their teaching roles. Consulted literature (Alberta Education 2015) confirms that correct interpretation of policies creates and maintains a disciplined and productive staff complement for schools.

The FET teachers also professionally gained knowledge of managing their classrooms. Classroom management involved preparing the classroom for learning and ensuring that the environment promoted learners' learning. This probably involved cleaning, mounting relevant charts and creating mathematical display corners from which learners learnt through the effort of others. The FET Grade 12 mathematics teachers who participated in school management teams professionally gained knowledge of managing and supervising colleagues. For these FET teachers, managing teachers in their teaching roles involved directing and controlling other teachers' activities while supervising teachers probably meant inspecting teaching documentation, making lesson observations and developing lesson appraisals to enhance their professional growth. Reviewed literature (Richman 2014) argues that the knowledge of managing and supervising teachers is a catalyst for change towards teacher effectiveness. In support, regarding managing affairs in the classroom, conceptual framework (Cogill 2008) explains that GPK offers the knowledge and skills teachers need to make and justify decisions in their roles.

Other participants (6) in PEIs explained that they professionally gained GPK related to assessment through collegial lesson observations. Teacher 10 explained that:

> *I learnt how to prepare my classroom for effective learning. I learnt how to assess other teachers' lessons and check the progress of their learners. I then gained knowledge of assessment which I used to make decisions for my teaching.*

Teacher 3 during FGD 1 explained: *"I learnt new methods of improving learners' performance from colleagues I assessed and that helped me to vary my teaching methods."* Knowledge related to preparing the classroom for learning, assessment and checking learner progress professionally gained by the FET Grade 12 mathematics teachers was critical for their professional growth. Consulted literature (Jennings 2017) suggests that classroom preparation for learning creates an enabling environment for teachers to perform their teaching roles effectively. This often includes preparation of the classroom to ensure a positive environment for learning similar to a farmer preparing his land to plant. Usually, a prepared classroom, as a conducive learning environment provides relevant content, clear learning goals, feedback and opportunities to develop social skills and strategies to help students succeed. Related literature (Young 2014) argues that a positive environment for learning is an investment that teachers can trust for learners to feel encouraged to tackle challenges, take risks and ask questions regarding their learning. Thus, knowledge of classroom preparation for learning is consistent with conceptual framework (Grossman 1990) which encourages teachers to design plans that promote the nature of the subject matter to direct the learners' learning.

GPK related to assessment that the FET Grade 12 Mathematics teachers gained in their teaching roles as exemplified by Teacher 10 and Teacher 3 is vital for providing the teachers with evidence of students' learning and of the effectiveness of their materials and strategies, which informs their instructional decisions. Surveyed literature (Jabbarifar 2019; Ramadan, 2014; Lawrence, 2019) perceives assessment as significant for demonstrating the quality and quantity of learning that takes place in the classroom and it also involves the assessment of classrooms as learning environments which can motivate learners to learn. Informed by conceptual framework (Cogill 2008), knowledge of classroom assessment includes how teachers frame social, individual and criterion-based activities to influence learners' motivation. Thus, knowledge of classroom assessment in teaching roles enables teachers to determine the learning styles, strengths and weaknesses of learners, as well as learners' interests (Ramadan 2014). Checking learners' progress involved the teachers in individual learner attention during instruction. Generally, teachers are responsible for seeing to each child's individual learning needs and progress in their teaching roles. Consulted literature (Grubb 2020) stresses the need to check learner progress as the teacher's basis for generating strategies for scaffolding learners through their individual learning challenges. But then, with the declaration of the education for all policy of 1994, enrolments in schools have sky-rocketed such that teachers are generally overwhelmed by enormous numbers in their classes and are unable to offer effective individual attention to learners. However, informed by conceptual framework (Hurrell 2013) these teachers through professional learning needed to be aware of their learners' progress as effective teaching is based upon the understanding of each learner.

Regarding the discussion above, GPK of classroom management gained by the FET Grade 12 mathematics teachers related to managing and organising activities of the teaching and learning process which included time, space and interactions with learners. This GPK gained was also related to creating conducive learning environments, assessment, individual attention of learners, maintaining learner discipline, interpreting policies, carrying out classroom assessments and making instructional decisions to cater for individual attention. The following section discusses pedagogical knowledge related to teaching strategies gained by FET teachers through professional learning in their teaching roles.

Pedagogical Knowledge related to Teaching Strategies

FET Grade 12 mathematics teachers professionally gained pedagogical knowledge related to teaching strategies through teaching roles. Pedagogy is viewed in conceptual framework

(Cogill 2008) as what individuals need to know and the skills they need to possess to make and justify decisions in their roles. Therefore, GPK of teaching strategies is perceived as that knowledge and skills teachers command in order to influence learners' learning. Generally, wide knowledge of teaching strategies is necessary for all teachers in their teaching roles to vary teaching approaches and enhance learner attainment during instruction. Reviewed literature (Goodwin 2018) perceives teaching strategies as structures, systems, methods, techniques, procedures and/or processes a teacher uses during instruction to facilitate learning. This is aligned to conceptual framework (Cogill 2008), supported by Guerriero (2017), that GPK includes structural designs and adaptivity. Structural designs cover the mapping of learning objectives, lesson planning and evaluation while adaptivity entails the creation of recipes for dealing with heterogenous learning groups to foster learners' motivation and learning.

GPK of teaching strategies that FET teachers professionally gained was confirmed by Teacher 1 during FF Interview 3 who said: *"We learnt teaching strategies from each other as colleagues. We learnt… new approaches helpful in our teaching."* Teacher 6 in PEI reported that: *"Whenever we gather as teachers in the cluster, we learn new teaching approaches from others helpful for organising our teaching programmes."* Through collaboration in their teaching roles, the FET Grade 12 mathematics teachers also professionally gained knowledge of teaching strategies. Conceptual framework (Shulman 1987) distinguishes the knowledge of teaching strategies in general pedagogy as significant for teacher competence. In addition, Guerriero (2017) and conceptual framework (Cogill 2008) advise that making good pedagogical decisions hinges on the quality of the GPK the teacher holds. Generally, teachers use different approaches to teach the same concepts. Proponents of teacher professional learning (EduTopia 2018) believe that teachers learn better together. Usually, teachers who work together professionally learn from one another and influence each other towards school improvement as is reflected above. Consulted literature (Goldstein 2015) asserts that when teachers meet, their individual interests, backgrounds, experiences and strengths are pulled together and coordinated towards their common goal of teaching. Thus, through shared experiences in their teaching roles, the FET Grade 12 mathematics teachers benefitted from increased affinity for excellence in professional practice. These teachers through inspiration from the success of others expanded their 'professional territories' and contributed other methods of teaching to colleagues.

FET Grade 12 mathematics teachers (18) through teaching roles professionally gained knowledge of teaching strategies for different forms of content. Ball et al. (2008) referred to teaching strategies of different forms of content as knowledge of content and teaching in PCK. Illustrating the knowledge of teaching strategies of different forms of content FET Grade 12 mathematics teachers professionally gained, Teacher 2 in FF interview 1 reported that: *"As teachers we learnt from our teaching experiences, discussed difficult topics and learnt different ways of how to teach them from one another."* The knowledge of how to teach different topics professionally gained by Teacher 2 is conceived of as a construct of knowledge that teachers need not just about teaching strategies but the specific strategies and representations of how to teach the various forms of content in the context of existing situations. This is the knowledge that distinguishes teaching strategies according to what content is being taught and the setting in which the learning occurs. Professional learning from each other's experiences raised in the quotation was vital for these teachers as it responded to genuine, different classroom challenges and seemingly gave these teachers confidence to approach topics that they once were afraid of. Drawing from theory (Ball et al. 2008) mathematics teachers need to secure skills for organising and structuring content in ways accessible to students known as 'teaching-oriented action'. This apparently is what happened with Teacher 2 where teachers discussed the difficult concepts, as well as appropriate strategies for teaching them, suggesting an amalgam of content and pedagogy alluded to earlier in this study. This is where teachers generate novel procedures guided by such questions as 'what do I teach from this content? and how do I teach it effectively in this context?'

Teacher 3 in PEI confirming the same sentiments reported that: "*I learnt different strategies of answering challenging mathematical problems which teachers put on social media to get insights from colleagues which gave us confidence in teaching."* Knowing different strategies of answering challenging questions professionally gained instilled teaching confidence for Teacher 3. Solving challenging problems seemingly improved these teachers' self-esteem in their roles. The new knowledge that these teachers professionally gained apparently motivated them to tackle all the content in the syllabus as opposed to approaching their content selectively for fear of humiliating themselves. This is consistent with theory (Ball et al. 2008) and reviewed literature (Scheiner 2017) that mathematics teachers must have an understanding of what makes the learning of specific topics easy or difficult. Professional learning knowledge regarding solving challenging mathematical problems through teaching roles is perceived in consulted literature (Schmidt, Baron and Thompson, 2014) as significant in instilling teacher confidence and increasing teacher capacity in their roles. '

Through their teaching roles some FET Grade 12 mathematics teachers (18) also professionally acquired knowledge of teaching strategies related to reflecting-in-practice. For example, Teacher 21 in FGD 4 reported that: *"I learnt to reflect on my teaching strategies during the lesson and found myself switching from one strategy to another there and then depending on the progress of my lesson."* From the response, Teacher 21 professionally gained the knowledge of reflection in their teaching. Knowledge of reflection-in-practice professionally gained by the teacher seemed to have enhanced their flexibility and they made appropriate modifications during lesson delivery. Drawing from theory (Ball et al. 2008) and conceptual framework (Cogill 2008) reflecting on one's strategies during the lesson often provides mathematics teachers with the most powerful analogies, illustrations, examples, demonstrations, explanations and ways of representing and formulating content to make it easily understood by learners. These teachers reported that this helped them to switch from one strategy to another within one lesson if one strategy failed during the course of instruction. Such competences tend to develop aesthetic professional values in individual teachers in their roles.

What emerges from the discussion above is that FET Grade 12 mathematics teachers professionally gained GPK related to classroom management and teaching strategies. Regarding classroom management, these teachers professionally gained knowledge related to managing time, space and interactions with learners in their pedagogical practices. They also professionally gained knowledge related to creating conducive learning environments, assessments, interpreting policies and making instructional decisions in their roles to cater for all their learners.

The FET Grade 12 mathematics teachers professionally gained knowledge of teaching strategies helpful in organising teaching programmes, like how to teach difficult and unfamiliar topics, different ways of working out challenging mathematical problems and reflecting on their teaching strategies in the course of a lesson. The GPK professionally gained by these teachers appears to have equipped the teachers with the capacity to manage their teaching roles in their pedagogical practices. These teachers also gained pedagogical content knowledge which is discussed below.

Pedagogical content knowledge

PCK is often perceived as what distinguishes teachers from one another in their teaching roles. Researchers (Shulman 1986; Ball et al. 2008; Park and Oliver 2008) embrace PCK as the professional knowledge domain needed to enhance instructional processes of the subject matter which includes the knowledge of students and knowledge of subject-specific teaching strategies and representations. However, unlike in Shulman (1987), Grossman (1990) and Cogill, (2008) where PCK was founded around what knowledge teachers needed to teach, PCK in MKT revolves around what knowledge teachers need in teaching where the latter emphasises knowledge for teaching rather than knowledge for teachers (Ball et al. 2008; Hill et al. 2008; Hurrell 2013). In this regard, knowledge for teaching refers to the knowledge mathematics teachers need for the process of teaching the subject to take place, whereas knowledge for teachers relates to the knowledge teachers need to prepare themselves to teach. Thus, the knowledge of students and teaching enables these teachers to organise, represent and adapt learning material to make it comprehensible in order to meet the needs and learning levels of diverse learners. Further, the knowledge of students in PCK represents the specific conceptions and misconceptions (Hill et al. 2013) that students bring to the teaching and learning process during teaching. However, knowledge of students, which is a separate domain (Shulman 1987; Grossman 1990; Cogill 2008) in this study, will be discussed as a separate theme. Participants' responses in this study suggest that PCK is an amalgam of knowledge of content and curriculum and knowledge of the contexts in which the teaching and learning process occurs. These sub-themes guide the discussion below, starting with knowledge of content and curriculum.

Knowledge of content and curriculum

The knowledge of content and curriculum was one form of PCK that the FET Grade 12 mathematics teachers reported to have professionally gained in their teaching roles. Usually, curriculum is a planned sequence of instruction or, specifically, what is taught in each subject at a given level. Ball et al. (2008), like Shulman (1987), defined curriculum as a full range of programmes put together for the teaching of a particular subject including topics at any given level and a variety of instructional materials like textbooks, teaching instruments and related technology. Thus, knowledge of content and curriculum is generally perceived as the knowledge professionally gained by teachers in their teaching roles about mathematics and the mathematics lined up for teaching in their subject area. Drawing on the theoretical framework (Ball, et al. 2008) teachers need to know the subject they teach more than just knowing its facts and concepts. Literature surveyed (Bertram 2011:7) views the knowledge of content and curriculum as the way in which a teacher restructures the content knowledge in order to make it better accessible to the learner. In this study, the knowledge of content and curriculum included what FET teachers needed to know about content in their curriculum and how it could be organised to give coherence and guided meaning to the teaching and learning process in their teaching roles.

24 FET Grade 12 mathematics teachers professionally gained the knowledge of content and curriculum related to interpretation of the Curriculum Assessment Policy Statement (CAPS) and other teaching documents and their effective implementation in their teaching roles. Teacher 12 in PEI explaining that they professionally gained knowledge of content and curriculum said: *"I learnt content I should teach from the CAPS document and the chief marker's report. I learnt how to break it into teachable units to ensure that the order of topics helps learners to understand concepts better during teaching."* Teacher 7 during FF Interview 1 expressing similar sentiments added:

> *I learnt the content I have to teach from reading curriculum documents. I gained better knowledge about how to teach the content in the curriculum. I learnt what content I should teach to prepare my learners for the next grade. This knowledge guided my choice of what to teach and how to teach it.*

Teacher 2 in FGD 1 added to the sentiments above saying: "*During lesson planning, I learnt content to teach from other policy documents. I learnt what content to teach from the CAPS document and chief marker's report and to what extent I should teach it."*. The three quotations above highlight professional knowledge gained related to content these teachers had to teach, how they could break the content into teachable units, arranging topics from the CAPS document in a manner that promoted concept formation and to what extent they had to teach each topic for each level of learners, all driven from the CAPS document. The CAPS document was a single comprehensive policy prescript introduced by the Department of Basic Education (DBE) for all the subjects listed in the national curriculum statement for Grades R - 12. According to Teacher 12 above, the discussion of the curriculum document was done so that teachers could understand the curriculum and re-organise it in their own fashion to meet their learners' needs. Drawing from theory (Ball et al. 2008; Grossman 1990) mathematics teachers must rethink the subject topics and concepts to make them more accessible to learners. Thus, the manipulation of the knowledge of content and curriculum for these teachers meant to facilitate the understanding of concepts by learners during teaching. Surveyed literature (Ennis 2012) indicates that teacher expertise is reflected in the abilities to select and teach content appropriate to the learner within a particular context and level. Teacher 7 raised knowledge professionally gained which related to a realisation of the link in the content from one level to the next. Drawing on Ball et al. (2008)'s perspective, the content and curriculum in previous and subsequent grades is known as "vertical" curriculum. This knowledge is usually necessary for teachers to 'build on' and 'build for' to achieve better learner understanding of concepts during instruction. The vertical curriculum was discussed in detail earlier in the section on knowledge at the mathematical horizon.

Teacher 2 and Teacher 12 confirmed that FET mathematics teachers professionally gained knowledge of content and curriculum from the chief marker's report. The chief marker's report is a profile of observations relating to learners' responses to examination questions compiled by chief markers to inform teachers for their future teaching. The knowledge from the chief marker's report professionally gained seemingly gave rise to better understanding of the content and helped to categorise it into teachable units in order to direct instruction appropriately and conveniently for comprehension. This is in tandem with the principles of Ball et al.'s (2008) theory which encourages teachers to breakdown content into teaching units for learners to easily understand it. Informed by consulted literature (Park and Oliver 2007), the knowledge of content and curriculum professionally gained by these teachers was seemingly central to their identification of core concepts, modification of activities and elimination of irrelevant information for effective instruction. Hence, teachers' knowledge of content and curriculum and their perceptions (Bell and Gilbert 2005) are instrumental in curriculum decision-making in their teaching roles.

19 teachers reported that curriculum documents were sometimes difficult to comprehend. Teacher 11 in FF Interview 1 explained this as follows: "*I learnt how to interpret the syllabus which is sometimes difficult to understand, in order to prepare learners well for examinations."* Through the knowledge of syllabus interpretation professionally gained, these teachers were likely to understand their content, the embedded concepts and their connections in that document. Consistent with theory (Ball et al. 2008 and Grossman 1990) the knowledge of content and curriculum enables teachers to make pedagogic interpretations connecting their knowledge of content to the interests and abilities of their learners. Reviewed literature (Bertram 2011) believes understanding of knowledge of content and

curriculum is important for relating and organising fundamental concepts by teachers to enable logical presentations of lessons in their teaching. This ensures that concepts are built one on top of the other rationally and hierarchically to enhance learner understanding.

From the discussion above FET Grade 12 mathematics teachers gained knowledge of content and curriculum for effective teaching and learning. The knowledge of interpreting the syllabus gained by these teachers was vital for appropriately selecting and sequencing the content to teach in relation to grades being taught. Besides professionally gaining knowledge of content these teachers also learnt the extent to which they could teach particular topics in each grade. Thus, they professionally gained knowledge of the horizontal curriculum which theory (Ball et al. 2008) refers to as vital for giving coherence to the learning processes. The next discussion covers pedagogical content knowledge related to knowledge of context, that the FET Grade 12 mathematics teachers professionally gained through their teaching roles.

Knowledge of contexts

Another aspect of PCK that was professionally gained by the FET mathematics teachers (18) through their teaching roles was knowledge of context. Based on conceptual framework (Shulman 1987; Grossman 1990) knowledge of context is a distinct domain different from PCK, which refers to the knowledge needed by teachers about their working environments, which helps them to make the best use of those settings and adapt instruction to meet their specific contexts. The knowledge of context has been related to PCK since content and teaching, as well as content and curriculum which feature in PCK, cannot be viewed out of context. Reviewed literature (Brant 2001) defines knowledge of context as the knowledge of all settings where learning should take place. This kind of knowledge influences the sequencing of topics on the curriculum and the performance of teachers and learners during the teaching and learning process (Ward 2009). Included in this domain is the knowledge of resources available, the norms and values of the school and communities in which the school is located, as well as the educational policies and standards governing the teaching and learning process. Informed by theory (Ball et al. 2008) this kind of knowledge is known as knowledge of school setting.

To explain the knowledge of context around mathematics resources at the FET phase, Teacher 1in FF Interview 3 explained that:

I learnt about materials and equipment available. Most learners do not have

> *calculators. I learnt that it is difficult to teach learners maths when they don't have calculators.*

Teacher 6 during PEI supported the above sentiments explaining that: *"I learnt how to keep and use school books and other materials learners need for their learning. … . Without these resources it is difficult to teach content and make progress."* Some FET mathematics teachers through teaching roles professionally gained knowledge of teaching and learning resources. Knowing available resources for teaching is usually critical for teachers to plan, prepare and deliver their lessons. Teacher 6 above was aware of limitations in the school context related to calculators. This is consistent with theory and conceptual framework ((Ball et al. 2008; Grossman 1990) that teachers' knowledge for use in the classroom must always be context-specific. Consulted literature (Tuimur and Chemwei 2015; Arop et al. 2015; Mtunjani 2016) argues that irrespective of any form of high quality of training, lack of equipment and materials for teaching will stop teachers from translating their competence into reality. Surveyed literature (Harrison 2013; Chase 2018) further indicates that learning resources are necessary for supporting student learning and paramount for increasing learner attainment.

Teacher 22 during FGD 4 reported about values and norms the FET Grade 12 mathematics teachers professionally gained that: *"I learnt the values and norms of the surrounding communities which guided my interaction with learners in the classroom."*. Teacher 4 during FF Interview 1 complementing the idea commented that: *"I learnt cultural beliefs of the surrounding communities which guided my behaviour among learners and in the classroom."* The FET Grade 12 mathematics teachers professionally gained knowledge of their communities in the form of norms, values and cultural beliefs which guided their interactions with learners. Reviewed literature (Tuimur 2015; Bakker and Hubmann 2017) argues that values are deeply embedded and critical guidelines for transmitting and teaching a culture of beliefs, while norms are rules and expectations that specify how people must behave in different situations and cultural beliefs are tenets that a society holds to be true. Generally, knowledge of the communities where teachers worked was helpful to teachers in their teaching roles. This knowledge influenced the manner in which teachers interacted with their learners and among themselves considering the cultures and beliefs that were prevalent in those areas. Informed by conceptual framework (Grossman 1990), understanding particular contexts helps teachers to adapt their general knowledge to specific school settings and specific learners. In the same vein, consulted literature (Lytle 2019), explains that the knowledge professionally gained from knowledge of communities includes ways of interaction, participation, interdependence, shared interests and beliefs and positive social relationships which encourage harmony in difference in the school.

Explaining knowledge of context related to school communities professionally gained, Teacher 14 in FF Interview 3 said: "*I learnt that teachers worked as a team and respected their organisational policies. Our district set a pass rate target of 75% and I learnt that it could be achieved through teamwork."* The school itself became a teachers' and learners' community of practice where joint enterprise, shared repertoire and mutual engagements become common features (Phillips 2012) in these teachers' teaching roles. Informed by conceptual framework (Grossman 1990), the knowledge of context enables teachers to adapt to each other, their own learners and the demands of their schools and districts to achieve the best in their roles. Through professional learning these teachers professionally gained the knowledge of context in the form of team work. Team work is generally the willingness of a group of people to work together to achieve a common task. Some FET Grade 12 mathematics teachers explained that they were expected to achieve a 75% pass rate by their District. This educational demand by their superiors often created shared interests and set these teachers to work collectively fostering interdependence. This created learning communities where teachers in their teaching roles adopted certain traits and practices because of their deliberate intentions to meet their institutional goals and policies.

From the discussion above, FET Grade 12 mathematics teachers professionally gained PCK related to knowledge of content and curriculum and knowledge of context. These teachers professionally gained knowledge related to curriculum content, the extent to which the content must be taught per Grade, how they could arrange topics to promote concept formation and break topics into teachable units. The knowledge of content and curriculum gave them insight into knowing how to interpret the syllabus, as well as knowledge of using and keeping resources in the form of materials and equipment. They also gained knowledge of norms, values and cultural beliefs including how to work as a team through their knowledge of context. PCK apparently emerged as a major teacher knowledge domain whose potential has probably not been fully realised in teaching roles to impact on learner achievement. The next section discusses knowledge of learners.

Knowledge of learners

The knowledge of learners (KOL) was professionally gained by 26 FET Grade 12 mathematics teachers through teaching roles. Ball et al. (2008), Scheiner (2017) and Celik and Guzel (2017) conceive KOL as what teachers professionally gain when they familiarise themselves with the interactions between specific mathematical understandings and learners' mathematical thinking which is necessary for engaging learners in mathematical learning. In learning situations, the KOL is usually basic and paramount for successful teaching. There is a general distortion in perception about teaching where, loosely, teachers think they teach content to learners when, conversely, they should teach learners the content (Eberly Centre 2019). Therefore, for effective teaching, teachers need to acquire relevant knowledge about learners in order to inform their teaching. Alber (2017) reiterates that teachers through professional learning need to generate as much valuable knowledge of learners as possible to inform their classroom practice. The FET Grade 12 mathematics teachers professionally gained the KOL related to learner abilities, learner conceptions and misconceptions and learner communication. KOL is discussed in relation to learner abilities.

Knowledge of learner abilities

In their professional learning through teaching roles, FET mathematics teachers (26) reported gaining knowledge of learner abilities which apparently influenced their engagement during instruction. More often than not teachers need to know the abilities, interests, and hobbies of their learners at each level of their learning as a strategy for teachers to connect well with learners in their teaching roles. In this context, learner abilities referred not only to their cognitive levels but also their physical, mental and emotional statuses. The FET Grade 12 mathematics teachers professionally gained the knowledge of learner abilities related to both social and academic behaviour and attitudes in and outside the classroom.

Teacher 13 during FF Interview 1 reported that: "*I got to know what individual learners like to do and what they are capable of doing.*" Similarly, Teacher 3 in PEI added: "*I was able to learn about the behaviours and characters of my learners in play and in class.*" Knowing learners' behaviour professionally gained often helps teachers to determine each learner's readiness for learning and create safe learning environments for all learners. Usually, teachers in their teaching roles want to increase learners' engagement and success. Thus, knowing learners' behaviour helps them identify multiple access points to the curriculum in their approaches. Mukeredzi (2013) noted that previously teachers did not pursue student knowledge systematically or rigorously: instead of generating and analysing that data for learning about their learners, they were satisfied with a general picture from ‘tidbits’ drawn out of essays or student journals, hints on student work, corridor conversations with previous teachers and so on. KOL is generally increasingly recognized as an essential component of teachers’ knowledge base for effective teaching in today’s classroom, which they should acquire. Guided by theory (Ball et al. 2008), when teachers choose examples, they need to predict what learners may find interesting, motivating and difficult. Thus, KOL usually guides the teachers towards the kind of teaching methods to use putting into account the learners’ concentration span, abilities and interests. Consulted literature (Konen 2017) advises that teachers should take their time to understand their learners in their social environments in order to develop dependable working relationships with them. The social environment for learners in this case refers to places of play and interaction with peers where learners mix and express themselves freely. Vygotsky (1978) in Castro-Felix and Daniels (2018:16) argues that: “an individual’s learning cannot be separated from their social environment.” Teacher 6 during FGD 1 further stated:

> *I learnt that learners concentrate on what they do during their play. Some concentrate on one thing for a long time while others concentrate for a shorter time.… The type of play helped me to know their forms of play which informed my choice of teaching strategies.* (Teacher 6 in FGD 1)

From the response, FET mathematics Teacher 6 professionally gained KOL related to learners’ behaviours and retention in play. Generally, learning through play captures learners’ attention and involvement. Such knowledge about learners often informs teachers on how they can make choices of lesson activities so that they attract learners’ involvement and attention during mathematics learning. Reviewed literature (Carrillo 2013) advises that teachers should modify tasks to accommodate learners’ interests and enjoyment of lessons. Retention raised by Teacher 6 is KOL which normally assists teachers to choose learner tasks appropriately in teaching roles. Informed by theory (Ball et al. 2008), KOL should guide teachers when assigning tasks to consider the strengths and weaknesses of learners based on their capabilities. Knowledge of learner abilities in teaching roles is usually vital for informing instructional procedures and processes. Teacher 1 during FF Interview 3 reported that: “*I learnt that learners need to be given challenging work according to their abilities so that those who excel keep going while those who are slow get encouraged.”* In the quotation above, FET Grade 12 mathematics teachers professionally gained KOL regarding learner diversity. Learner diversity is simply an acknowledgement that learners in any class are and will always be different. For South African schools, handling learner diversity is a prerequisite for teachers following the introduction of the inclusive education (IE) policy of 1994. However, consulted literature (Mahlo 2017) points out that handling learner diversity remains a challenge for many teachers, hence, the need to professionally acquire KOL. Informed by theory (Ball et al. 2008) mathematics teachers must cater for learner diversity as they anticipate what learners may think or find confusing when preparing for instruction. For these FET Grade 12 mathematics teachers, it would appear that learner diversity prompted a desire to recognise and respect their learners for who they were and treat them with tolerance.

In conclusion, FET Grade 12 mathematics teachers through their teaching roles professionally gained the KOL related to their abilities. The knowledge of learner abilities was professionally gained through knowing learners' behaviours, their retention of attention and diversity. The knowledge of the learners regarding their behaviour, attention retention and diversity is critical for mathematics teachers whose many demands for teaching require their knowledge of content and students (Ball et al. 2008). The subsequent section discusses knowledge of learner conceptions and misconceptions.

Knowledge of learner conceptions and misconceptions

The knowledge of learner conceptions and misconceptions professionally which was reportedly gained by 26 FET Grade 12 mathematics teachers in their roles, is knowledge of what learners know correctly and incorrectly in the context of their curriculum content. Usually this is knowledge that is professionally gained when teachers seek to establish the gap between what learners know and what they are expected to know. The difference that exists between what the learners know or do not know and what they must know usually determines the mathematical knowledge gap that learners may experience which teachers must consider in planning and preparing for instruction. According to theory (Ball et al. 2008), such is the knowledge teachers need to familiarise themselves with, the mathematics content that they ought to teach. This is knowledge-in-practice according to reviewed literature (Kelly 2006) with which FET teachers in their teaching roles should meet learners' learning needs. Thus, effectiveness in teaching is supported by the application of relevant knowledge about learners to direct the teachers' instructional practice. Supported by theory (Ball et al. 2008), teachers must consider learners' conceptions and misconceptions when building on learners' mathematical ideas.

All the FET mathematics teachers (26) reported professionally gaining knowledge of learners' conceptions and misconceptions through teaching roles. Teacher 8 during FF Interview 3 explained: *"I learnt about teaching gaps in my learners. During discussions I usually can see those learners who have grasped the concepts and those who have not understood the concepts during teaching."* From this response, in their teaching roles, FET mathematics Teacher 8 professionally gained knowledge of learner conceptions and misconceptions related to teaching gaps. Teacher 8 learnt to identify and distinguish among learners who have mastered concepts and those who have misunderstood the concepts during instruction. I perceive teaching gaps as disparities that occur when learners have missed what was taught or teachers omit some content in their teaching which is necessary to lead learners to new learning. Such knowledge has the effect of informing the teacher about what to do next to meet instructional goals. Teaching gaps are familiar challenges for many mathematics teachers in their roles. From the conceptual framework (Hurrell 2013), teachers do not comprehend the same way as their students, therefore, they should recognize and overcome their expert blind spots by interacting with learners during and after instruction. Mathematics teachers need to regularly spot teaching gaps among learners, as gaps can make struggling learners fall behind and fail to master new material which normally depends on what was learnt previously. However, often when teachers realise their teaching gaps, they tend to hide them from colleagues who could otherwise help them in their roles. Drawing on Ball et al.'s (2008) theory, teachers must be able to hear and interpret their learners' emerging and incomplete thinking about their learning in mathematics. In support, surveyed literature (Alber 2011) urges teachers to diagnose learners' misconceptions to establish how well learners make sense of the content delivered to them and to what extent those learners struggle in their learning. Identifying learners' misconceptions in this regard, would probably reduce learner challenges caused by teaching gaps and promote curriculum goals in the FET Grade 12 mathematics teachers' roles. Thus, the knowledge of learner conceptions and misconceptions professionally gained is central to the praxis of teaching and the learning of mathematics.

Through their teaching roles, the FET Grade 12 mathematics teachers (26) also reported professionally gaining the knowledge of learner conceptions and misconceptions through the identification of misconceptions in written work. For example, Teacher 15 during FF Interview 1 explained that: *"As I mark the learners' work, I often learn what the learners* *would have understood and from their mistakes I learn the nature of learner misconceptions."* Teacher 13 during PEI concurred: *"From the written work that I mark, I usually learn learners' misconceptions which help me to prepare for the next lessons."* The reports by Teacher 15 and Teacher 13 show that they professionally gained knowledge related to identifying the nature of learners' misconceptions from learners' written work and tried to capture those misconceptions during their preparations for subsequent lessons. This is given that lesson preparation is often regarded as professional practice around which successful teaching and learning hinges especially when it is supported by KOL. Theory (Ball et al. 2008) encourages teachers to invest in evaluating learners' understandings and misunderstandings as a means towards effective lesson preparation. Taking into account the learners' misconceptions, lesson preparation tries to accommodate all learners in the class and boost learner involvement which is critical for teacher effectiveness. As misconceptions are generally regarded as gaps in concept formation which result in wrong ideas about a concept, reviewed literature (Foster 2018) stresses that knowing where learners are in mastering the content or not mastering it can inform teachers in preparing for instruction in their roles. In fact, learning is generally as much about unlearning old ideas as it is about learning new ones. While mathematics misconceptions may retard learner progress in learning new concepts and excelling, teacher knowledge of learner conceptions and misconceptions would probably support learners to shift in their thinking during instruction. Surveyed literature (Sadler 2016; Zuya 2014) encourages teachers to know learners' misconceptions as they attribute such knowledge to learner achievements. Therefore, knowing the nature of learners' misconceptions would guide FET Grade 12 mathematics teachers towards effective ways of preparing for instruction to help all learners master concepts and limit misconceptions. To emphasise, theory (Ball et al. 2008) considers knowledge of learner conceptions and misconceptions as central to any effective and meaningful teaching.

To conclude, the FET Grade 12 mathematics teachers professionally gained the knowledge of learner conceptions and misconceptions through teaching roles. The knowledge of learner conceptions and misconceptions professionally gained by these FET Grade 12 mathematics teachers related to teaching and learning gaps and linking previous content to new lessons in their teaching roles. Thus, the teachers learnt to identify and distinguish among learners who mastered concepts and those who misunderstood the concepts during instruction. They also gained knowledge related to identifying the nature of learners' misconceptions from learners' work and tried to capture those misconceptions during preparations for subsequent lessons. The knowledge of learner conceptions and misconceptions was portrayed as teacher knowledge significant and necessary for effective and meaningful teaching in teachers' pedagogical practices.

CONCLUSION

This chapter discussed the kinds of knowledge that FET mathematics teachers professionally gained through teaching roles. The discussions were based on Ball et al.'s (2008) Mathematical knowledge for teaching theory, complemented by other conceptual frameworks (Cogill 2008; Grossman 1998) and literature. The findings identified subject matter knowledge (SMK), specialised content knowledge (SCK), general pedagogical knowledge (GPK), pedagogical content knowledge (PCK) and knowledge of learners (KOL) as the major kinds of professional knowledge these teachers gained.

Firstly, FET mathematics teachers professionally gained SMK in the form of common content knowledge and knowledge at the mathematical horizon. This was knowledge that encouraged accuracy in mathematical operations and connections between different applications of mathematics. The common content knowledge professionally gained included in-depth knowledge of topics in their curriculum and the use of mathematical content in different settings other than the school. Knowledge at the mathematical horizon that was professionally gained related to understanding the vertical and lateral (horizontal) curricula. These teachers further gained knowledge of the application of mathematics in real life. Secondly, SCK was professionally gained by the FET Grade 12 mathematics teachers as knowledge of specific content in their curriculum and strategies and skills peculiar to teaching the specific topics. The SCK related to knowledge of critical thinking and problem-solving was also professionally gained as knowledge of guiding their learners in problem-solving, listening to learners' arguments, solving mathematical problems step by step and identifying key words and clues in answering questions.

Thirdly, GPK regarding classroom management and teaching strategies was professionally gained by FET Grade 12 mathematics teachers through their teaching roles. Concerning knowledge of classroom management, the FET Grade 12 mathematics teachers professionally gained knowledge related to managing materials and resources for teaching like time, space and context. Knowledge of classroom management was experienced as knowledge of interpreting school policies, supervising learners and other teachers, as well as reflecting on learner assessment tasks. In addition, the teachers gained knowledge of teaching strategies where they learnt new strategies for teaching different and difficult content, ways of answering challenging questions and reflecting-in-practice. Fourthly, knowledge of content and curriculum and knowledge of context constituted professional knowledge gained under PCK. The knowledge of content and curriculum that was experienced related to knowledge of interpreting the syllabus, the content to be taught and the extent to which it should be taught in their Grades, breaking the content into teachable units and different ways of arranging curriculum content to promote concept formation. The knowledge of context in PCK was professionally gained as knowledge of cultural beliefs, values and norms, using and keeping learning resources.

Finally, the KOL, which involves knowing the abilities of learners, their conceptions and misconceptions and their ways of communication, was professionally gained by FET Grade 12 mathematics teachers through teaching roles.

The next chapter focuses on the influence of teacher knowledge gained through their pedagogical practices.

CHAPTER SIX

DATA PRESENTATION AND ANALYSIS: INFLUENCE OF PROFESSIONAL LEARNING ON FET GRADE 12 MATHEMATICS TEACHER PEDAGOGICAL PRACTICES

Introduction

The study sought to understand how FET Grade 12 mathematics teachers engage in professional learning through their teaching roles, the types of knowledge they gain and how the learning influences their pedagogical practices. Chapter Four, the first data presentation and analysis chapter, addressed Question One on the nature of professional learning, where it emerged that learning occurred within two sites: the school site and the wider professional site through engagement in classroom practice, and formal and informal activities. The preceding chapter addressed Research Question Two on kinds of professional knowledge the teachers gain through teaching roles. Findings show that the teachers professionally gain subject matter knowledge (SMK), specialised content knowledge (SCK), general pedagogical knowledge (GPK), pedagogical content knowledge (PCK), and knowledge of learners (KOL).

This chapter, the third and final data presentation and analysis chapter, answers Research Question Three: *In what ways do the teachers say their professional learning influences their pedagogical practices?* Findings show that professional learning influences FET Grade 12 mathematics teachers' pedagogical practices around classroom behaviour and communication, managing learner discipline and teaching and learning resources. As detailed in the methodology chapter, I adopted a three interview-series approach (Seidman 1988) where I interviewed each participant three separate times. Hence, in presenting findings, interviews are identified as Interview 1, 2 or 3 and Interview 2 (Photo-Elicitation) is represented by PEI.

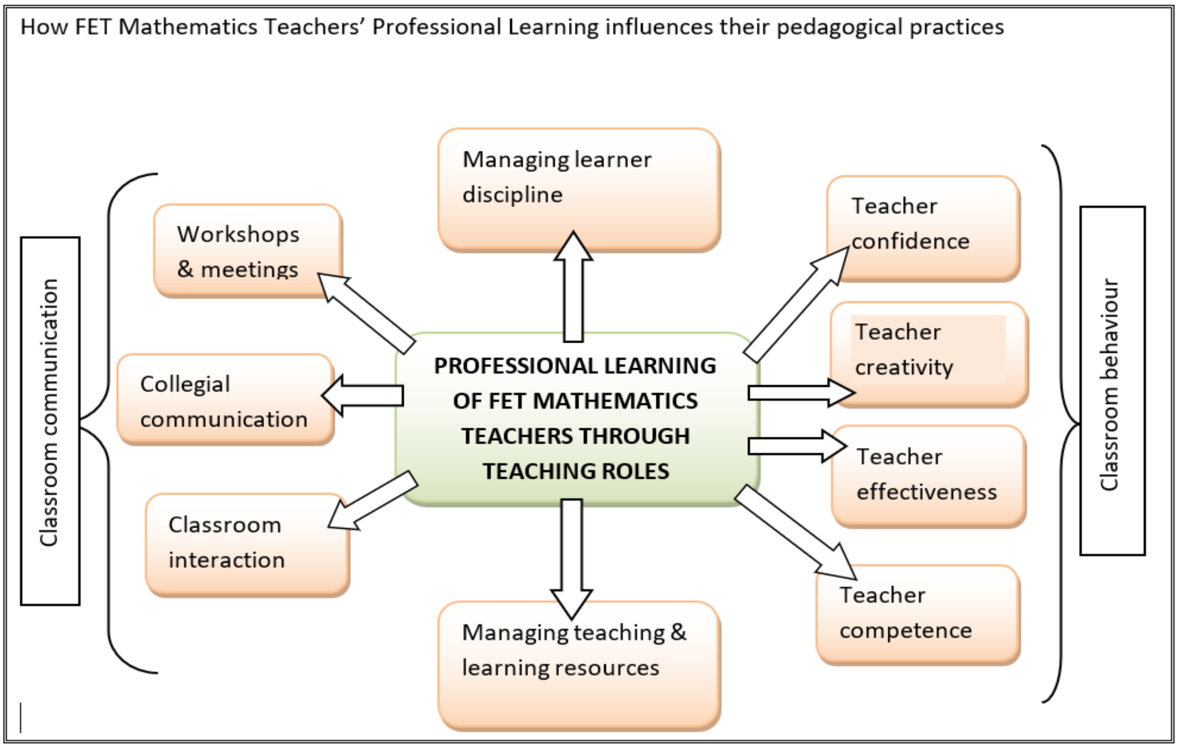
The influence of professional learning on FET Grade 12 mathematics teachers' pedagogical practice discussed in this chapter draws on Ball, Thames and Phelps's (2008) mathematical knowledge for teaching (MKT) around what constitutes effective mathematics teaching at various levels. This is complemented by Cogill's (2008) and Grossman's (1998) conceptual frameworks around characteristics of good classroom pedagogical practices.

The next section discusses themes that emerged from the data.

Themes that emerged

Four major themes were identified through data analysis: classroom behaviour, communication, managing learner discipline and managing teaching and learning resources. Figure 6.1 presents a synopsis of the ways that the FET Grade 12 mathematics teachers said professional learning influenced their pedagogical practices.

Figure 6.1: ***Influence of FET Grade 12 mathematics teacher professional learning on pedagogical practices***



Source: Researcher (2021)

Figure 6.1 reflects the themes and sub-themes which frame this chapter in answer to Research Question Three. The themes, starting with classroom behaviour, are discussed through their subthemes. Following the discussion on themes and subthemes, the chapter is tied up in a conclusion. Preceding the discussion, Table 6.1 reflects participants' responses regarding the influence of professional learning on FET mathematics teacher pedagogical practices.

Table 6.1: ***Numbers of teachers who indicated professional learning influence on different aspects of pedagogical practices***

Themes	**Classroom behaviour**				**Communication**		**Managing learner discipline**	**Managing teaching and learning resources**
Sub-themes	Teacher confidence	Teacher creativity	Teacher effectiveness	Teacher competence	Classroom communication	Collegial communication		
Totals	**26**	**17**	**21**	**13**	**26**	**15**	**26**	**14**

Source: Researcher (2021).

Table 6.1 gives a summary of the number of teachers who made references to the influence of FET Grade 12 Mathematics teacher professional learning on different pedagogical aspects. The subsequent section discusses professional learning influence on classroom behaviour.

Classroom behaviour

FET Grade 12 mathematics teachers reported that their professional learning through teaching roles influenced the way they engaged in pedagogical practices in their classrooms. Reviewed literature (Kelly 2009) conceives teacher classroom teaching behaviour as involving all teaching activities that offer the teacher some learning-in-practice which influences their professional efficacy. Findings indicate that professional learning influenced FET Grade 12 mathematics teachers' classroom behaviour in four ways: teacher confidence, teacher creativity, teacher effectiveness and teacher competence. Drawing from my theoretical framework (Ball et al. 2008) these influences revolve around the expectation that mathematics teachers must be well informed about their roles as teachers. These aspects are discussed in turn below commencing with teacher confidence.

Teacher confidence

All FET Grade 12 mathematics teachers (26) reported that professional learning through their teaching roles influenced their confidence in teaching curriculum content. Usually, teachers who have confidence in their work, have power and authority in what they say and do, thereby instilling confidence in their learners and commanding respect among them. Informed by Ball et al. (2008), mathematics teachers must be confident about their content and present mathematical ideas in simple but effective ways. The FET Grade 12 mathematics teachers explained that their professional learning influenced their pedagogical practices as they became more comfortable in curriculum delivery. Commenting on how professional learning influenced their confidence, Teacher 7 during PEI reported that: *"I no longer lack confidence with any of the topics in my subject. I am now very confident with all my stuff. I can now teach any concept in the syllabus comfortably."* Other participants during FGDs and FF Interviews also contributed to the above sentiments. For example, Teacher 11 during FF Interview 3 said: *"Professional learning has improved my confidence to teach and manage my content. I am now confident in my subject content."* In addition to above sentiments Teacher 7 in FGD 2 reported that: *"I certainly approach my work with confidence now as I am familiar with the content and the ways of teaching it."*

The three quotations above reveal that professional learning influenced FET Grade 12 mathematics teachers' pedagogical practices as they became confident with their content and teaching approaches. Development of confidence may be attributed to familiarisation with the curriculum content and teaching approaches that the teachers acquired through their professional learning. Consulted literature (Mukeredzi and Nyachowe 2018) perceives teacher confidence as self-assurance which arises from individual appreciation of personal abilities and qualities. Thus, teacher confidence is often perceived as believing in oneself about what one is capable of doing which makes a teacher comfortable in their practice. Surveyed literature further (Lomba 2014) asserts that confidence in teaching encourages teachers to excel in their teaching roles as reflected in the responses above. Complementing the idea by Lomba above, other reviewed literature (Bertram et al. 2013) comments that lack of confidence has negative implications in professional practice. These teachers valued the professional learning influence regarding their confidence as they could approach their work differently. Confirming the value of confidence, Mukeredzi and Nyachowe (2018) argue that self-confidence remains the greatest motivator and regulator of professional behaviour in the classroom. For some of these teachers, self-confidence was always undermined during apartheid (Bertram et al. 2013). Confidence arising from professional learning in their teaching roles apparently boosted their pedagogical practices.

Theory (Bell and Gilbert 2005) confirms that confidence is built around learning from colleagues' teaching experiences and personal over-time experience in teaching the same curriculum. One of the teachers reporting on how professional learning through teaching roles influenced their pedagogical practice said: *"Professional learning improved my teaching confidence. I now know new approaches and teaching methods of presenting some topics and how to vary them as I explain some concepts in my work. I now enjoy my work,"* (Teacher 7 during FF Interview 3). From this quote teacher professional learning influenced the FET Grade 12 mathematics teacher pedagogical practice regarding the new ideas about presenting content and ways of explaining concepts. In other words, professional learning influenced the pedagogical practices of the teachers as they were now able to explain concepts more clearly. The ability to vary approaches and teaching methods during instruction apparently improved these teachers' pedagogical practices thereby enhancing their confidence. Conceptual framework (Hurrell 2013) describes these novel executions of instructional processes by teachers as 'special forms of professional understanding' which develop self-confidence in teachers. This is consistent with Vygotsky (1978 in Kim 2001) who proclaims that teachers in their pedagogical practices are learning facilitators in their classrooms and should steer the instruction process towards learners' learning expectations. Further reviewed literature (Villegas-Reimers 2009) shows that the development of teacher confidence is critical to teacher classroom practices and lack of it affects teacher attitudes and behaviour towards their teaching roles. I subscribe to views by Mukeredzi and Nyachowe (2018) that self-confidence for teachers is long-lasting and of benefit if it arises from teachers meeting their challenges in their pedagogical practices and if they are supported in their endeavours.

Therefore, professional learning through teaching roles seemingly influenced the confidence of FET mathematics teachers in their pedagogical practices regarding their knowledge and management of curriculum content, as well as teaching approaches. The FET Grade 12 mathematics teachers also reported professional learning influence on pedagogical practices regarding creativity which is discussed below.

Teacher Creativity

Findings further show that professional learning influenced FET Grade 12 mathematics teachers' pedagogical practices related to their creativity. Craft (2010: 10) defines teacher creativity as an "imaginative activity fashioned so as to produce outcomes that are both original and of value." Consulted literature (Sternberg 2013) perceives creativity as original valuable ideas that teachers develop which explore their personal passions in their roles. Based on Ball et al.'s (2008) MKT theory, mathematics teachers must be able to connect mathematical ideas to representations that make learning easy for learners. Thus, creativity may be construed as the art of variation of processes, methods, approaches and strategies of teaching during classroom practices.

17 FET Grade 12 mathematics teachers reported that their creativity improved which

promoted learning effectiveness in the classroom. For example, Teacher 7 during PEI reported that*: "Now my lessons are varied and effective. I am creative such that my lessons are no longer monotonous."* Teacher 7, above, alludes to these teachers' novel presentations of lessons through creativity acquired from professional learning in their teacher roles which made lessons lively. Drawing on conceptual frameworks, Cogill (2012) argues that teacher professional learning through teaching roles instils creativity and, hence, flexibility in lesson delivery and management of instructional processes which may enhance learner achievement. Arguments in consulted literature (Liu and Wang 2019) have it that developing creativity among teachers develops new products that meet demands for new approaches and strategies for teaching in a rapidly changing world. Therefore, teacher creativity relates to teachers adapting their teaching strategies to different situations which adds value to their classroom practice. Drawing from theory (Ball et al. 2008), teachers in their pedagogical practices should develop inspiring mathematics lessons which keep learners alert and challenged to think creatively. In addition, conceptual frameworks (Cogill 2008) emphasise the need by teachers to create a relaxed and enjoyable atmosphere in their pedagogical practices. Preventing monotony during instruction keeps learners focussed, engaged and involved in the intended activities of learning all the time.

Reports from FET teachers further elaborated that creativity influenced their lesson delivery making their lessons interesting and varied for their learners. Teacher 10 during FGD 2 added that: *"I can now make reasonable imaginations to make lessons more exciting and relevant."* According to Teacher 10 above, use of reasonable imaginations referred to well thought-out, original and creative examples that the teacher used to demonstrate some concepts during lesson delivery. The findings imply that the use of reasonable imaginations made the process of instruction more interesting to both the teacher and their learners during pedagogical practices. Teacher 10 indicated that professional learning through teaching roles influenced FET Grade 12 mathematics teachers to become original and creative in their teaching.

Another teacher reported that creativity inspired learners' interest to learn the content and also encouraged them to learn creatively. Teacher 6 during FF interview 3 reported that: *"Professional learning exposed me to new thinking. Now I am able to inspire my learners to think creatively and independently to solve mathematical problems in their content."* The FET mathematics teacher explained that professional learning opened them to new ideas during pedagogical practices. Surveyed literature (Craft and Jeffrey 2020) makes assertions that creative teachers constantly reflect on their work and are prepared to learn from learners without fear of looking foolish which develops effective professional learning and growth in the classroom. Elaborating how professional learning related to creativity brought about reflection, Teacher 17 during FGD 3 reported that: *"I now reflect on my lessons and from my errors I think out solutions. That way I am now creative so that I have improved my delivery."* Generally, when teachers discover their errors through reflection, they endeavour to correct them thereby becoming creative and better, in which case this influences their pedagogical practices. Confirming creativity and learning through reflection, reviewed literature (Mukeredzi 2015; 2019) notes that self-reflection provokes thinking and initiates analysis which leaves teachers in their pedagogical practices better than before. In this regard, exposure to new thinking is important to break the monotony in teachers' ways of performing their teaching roles. Thus, these teachers' creativity in their pedagogical practices enabled them to influence their learners to be creative. Reviewed literature (Teach Thought 2013) advises that teachers should be prepared to get out of their comfort zones in order to develop their creativity. Teacher creativity is informed by theory (Ball et al. 2008) which proclaims that teachers should be able to articulate content and pedagogy in their own creative form of professional understanding, which conceptual framework (Cogill 2008) refers to as proper judgement of learner expectations.

Teacher 17 above suggested professional learning influenced the teacher's independence in their pedagogical practices. Teacher independence suggests that these teachers became autonomous in their pedagogical practices. Reviewed literature (Mukeredzi 2015) defines teacher independence as involving teachers' capacity to engage in their responsibilities and become self-determined, directed and regulated to attend to their roles. Teacher independence in this regard promoted teacher freedom to manipulate their pedagogical practices and to remain located central to their knowledge construction which, in turn, improved learners' participation in problem-solving. Drawing from conceptual framework (Cogill 2008), teachers in their pedagogical practices must present work freely in interesting and motivating ways for learners. Thus, teacher independence is critical for promoting effective learning in the classroom. From the discussion above, the findings suggest that professional learning through teaching roles influenced FET Grade 12 Mathematics teachers' pedagogical practices regarding creativity giving rise to flexibility in lesson delivery, inspiring creative and independent thinking among learners, and reflecting on lessons taught. These teachers' professional learning also influenced their pedagogical practices related to their effectiveness as discussed below.

Teacher effectiveness

The findings further indicated that many FET Grade 12 mathematics teachers noted the influence of professional learning related to classroom behaviour on their effectiveness. Teacher effectiveness in surveyed literature (Skelton 2018) is viewed as the impact of the teaching process which has a positive influence on learners' achievements. Teacher effectiveness is generally perceived through some set criteria, available evidence and provided standards to be met by those teachers through teaching roles. Hence, there must be evidence of how well the work has been accomplished and a standard against which the work is compared for rating in order to declare performance as effective. In South Africa, teacher effectiveness is measured through integrated quality management systems (IQMS) (DBE 2016) as alluded to in Chapter One. In IQMS teacher performance is rated from 1-5 for every aspect of their pedagogical practices measured, where 5 represents exceptionally excellent work while 1 stands for mediocre work calling for professional development for the teacher to improve. However, IQMS has been affected by too much paper work and its association with remunerations and not genuine performance measurement, which frustrates teachers. Thus, teacher effectiveness relates to attributes of effective teaching, a record of the review process and the expected quality and quantity of performance by teachers in formative and summative evaluation processes.

The FET Grade 12 mathematics teachers (21) reported that professional learning through teaching roles made them more effective in their pedagogical practices. Teacher 5 during FGD 1 elaborated that: *"I am now effective in my work. My school used to have a pass rate of less than 40% but now our pass rate is 72%."* In his report, Teacher 5 believes their professional learning influenced their pedagogical practices in relation to their effectiveness, consequently, improving the school pass rate. While it may not be disputed that teacher effectiveness may have enhanced the school pass rate, however, it may also be argued that other factors such as improved resources, learners' personal efforts, leadership and others may have played a role in raising the pass rate. Borrowing from the assumptions of social constructivism theories (Vygotsky 1978; Bandura 1978; Kim 2001) learning is a social process, hence, may not depend solely on teacher effectiveness. In a clear disregard of attributing learner achievement to a single factor such as teacher effectiveness, research (McCallum et al. 2000; Keates and Gold 2007; Hopkins 2008; Khumalo 2014) identifies a list of factors to that effect. Through consulting learners, Hopkins and others identified classroom conditions, learner ability, age, learner focus and others as contributing to learner achievements besides teacher effectiveness. To confirm ideas from research, consulted literature (Hopkins 2008: 393) argues that, "a school can only be the best it can when learners are actively engaged in contributing to school improvement through working with the staff." However, findings seemingly indicate that effective teaching remains central to these teachers' professional learning influence on pedagogical practices as they became able to scaffold learners to better attainment. Teacher 5 during FF Interview 3 reported that: *"I became effective through learning from others and being open to advice from experts."* The way in which professional learning influenced FET Grade 12 mathematics teachers' pedagogical practices was also realised in the openness to learning from others which seemingly enhanced their effectiveness. Reviewed literature (Guskey 2003) foregrounds teacher openness to learning by advocating for continuing professional teacher development for professional growth. CPTD alluded to in Chapter One has been adopted by the South African Council for Educators (SACE) as a compulsory programme for all teachers in South Africa to enhance effectiveness in their roles. However, emphasising openness to learning, consulted literature (Haney and Beltyukova 2012) confirms that teachers who engage in professional learning have significant gains in their teaching and efficacy. However, with regard to teacher effectiveness Muijs (2014) found that this is determined through classroom practice as a predictor of learner outcomes. Ball et al.'s (2008) MKT theory indicates that teachers need to have their own way of effectively articulating content and pedagogy in the mathematics curriculum.

From the discussion above, the FET Grade 12 mathematics teachers' professional learning influenced their effectiveness depicted in improved ways of teaching during their pedagogical practices, enhancing school results and including improved openness to learning. The next section discusses how professional learning influenced teacher competence.

Teacher competence

Professional learning influenced the pedagogical practices of some FET Grade 12 mathematics teachers in their roles in relation to teaching competence. Teacher competence from consulted literature (Selvi 2010: 168) involves "knowledge, skills, attitudes, values, motivations and beliefs" that teachers possess, which enhance effectiveness in their teaching roles. The definition of teacher competence above shows that competent teachers are knowledgeable of their content and skilled in their practice and they display the right attitudes, values, motivations and beliefs in their classroom roles. Informed by Ball et al. (2008), mathematics teachers have to know their content, use mathematics notation and language accurately and be able to critique its use by others. International research findings (Haamoonga 2017; Norris 2012) confirm that teacher competence, among other factors, improves learner performance and contributes to the quality of an education system.

Some FET mathematics teachers (13) commented that professional learning enhanced their competence which impacted on their learners' performance. Teacher 11 during FF Interview 3 commented that: *"I am now competent in my content. I am requested to facilitate some workshops to help other teachers because of my competence."* Teacher competence was also raised by another participant who said: *"Now I know what learners need to pass their matric examinations. ... Now I am competent that I can prepare my learners to pass their examinations."* (Teacher 3 in the PEI). From the quotations above, the influence of teacher professional learning on FET Grade 12 mathematics teacher competences suggests that their knowledge of content, including skills of imparting that knowledge, had improved. Through the acquired competence, these teachers were seemingly able to discern from their curriculum what and how to prepare and disseminate the content learners needed to learn and enhance success in examinations. Ball et al.'s (2008) theory suggests that mathematics teachers must be familiar with their content and be able to select appropriate representations to illustrate the content in order to influence learner understanding and achievements.

Teaching for examinations raised in the quotation above is significant in teachers' pedagogical practices. However, generally, when teachers teach for passing examinations, it may not be teaching as usual, as there may be a shift in their pedagogical practices, a shift in order in the classroom, in the sitting arrangement, a shift in the written exercises and other aspects may also change. Surveyed literature (Cyril 2013) portrays teaching for examinations as teaching only the content that is likely to appear in upcoming examinations. Wayman (2005) explains that teaching for examinations has clear goals, motivates learners and has valuable feedback to teachers for instructional decision-making. On the other hand, focussing on what is expected in examinations may have the effect of narrowing teacher flexibility in instructional design and decision-making, decreasing the use of a rich curriculum and posing a threat of sanctions for not meeting set criteria which may frustrate the teacher in his/her role. Surveyed literature (Cyril 2018) shows that focussing on what is expected in examinations is inevitable: the examination focus remains central for teachers because of the consequences the examinations have for both themselves and learners. Conceptual framework (Cogill 2008), suggests that teachers must help learners with difficulties and encourage them to raise their expectations to pass examinations. Ball et al. (2008), advises that when teachers are competent, they carefully choose content and strategies of instruction and they do not waste time on peripheral content without effect. Through enhanced competence in their teaching roles, their learners' zeal to achieve may have been aroused and this probably motivates them to excel in their work. While teacher competence may be a factor influencing success in examinations, several other factors such as learners' focus, availability of teaching and reading materials and group discussions, as alluded to above, may also have played a part. Although teacher competence may be influenced by many factors, literature reviewed (Williams 2001) suggests that teacher professional learning has the effect of elevating teacher competence to desirable standards. Williams encourages teachers in their teaching roles to professionally learn in order to enhance competence, as is alluded to in the quote above, as this influences learner performance. To this effect, theory (Ballet al. 2008) encourages teachers to know learners and their characteristics in order to competently influence their performance. Thus, professional learning through teaching roles seemingly influenced FET Grade 12 mathematics teachers' pedagogical practice in relation to their competence.

From the discussion above, while this is reported data, professional learning seemingly influenced FET Grade 12 mathematics teachers' pedagogical practices around classroom behaviour in relation to teacher confidence, creativity, effectiveness and competence. Teachers reported that they had developed confidence as they were now able to manage and teach the content comfortably as a result of professional learning. The teachers further reported gaining skills of creativity as they could propagate reasonable imaginations to make their lessons exciting. Through effectiveness achieved from professional learning, the FET Grade 12 mathematics teachers managed to influence learners' achievements and, hence, the improved school pass rate. Lastly, these teachers reported the influence of professional learning on their pedagogical practices related to skills of imparting the content, as well as improving their attitudes, values, motivations and beliefs in their teaching roles. Professional learning influence on these teachers' confidence, creativity, effectiveness and competence brought about different experiences in their classroom practices which they reported to have improved learners' performance. The subsequent section discusses how professional learning influenced FET Grade 12 mathematics teachers' pedagogical practices regarding classroom communication.

Communication

FET Grade 12 mathematics teachers (26) also reported that they experienced professional learning influence related to communication in the classroom. Communication is often regarded as a networking process that relates to the art of sharing messages with learners through teaching and receiving learners' feedback which is vital for effective instruction. Consulted literature (Ministry of Education, Guyana 2015) conceives communication as verbal, non-verbal or written means by which teachers and learners transmit messages and information which increase understanding between them during instructional processes. Drawing from Ball et al. (2008) mathematics teachers should be able to communicate concepts to learners in clear and precise terms by choosing and developing useable definitions. The theme of communication is discussed through classroom communication and collegial communication as sub-themes, around which professional learning influenced pedagogical practices of FET Grade 12 mathematics teachers in their teaching roles. The following section discusses professional learning influence on FET Grade 12 mathematics teachers' pedagogical practices related to classroom communication.

Classroom communication

The influence of professional learning on FET Grade 12 mathematics teachers' pedagogical practices which related to classroom communication involved interactions between the teachers and their learners in the classroom. Consulted literature (Hanum 2017) defines classroom communication as speech and symbolic messages shared between teachers and their learners which enhance the instructional process. Normally, classroom communication aims at providing clear understanding of information between teachers and their learners which is vital for effective learning. Ball et al. (2008) advises that mathematics teachers have to find their learners by adopting representations that illustrate concepts more than their explanations alone would do.

Confirming the influence of classroom communication on their pedagogical practices Teacher 5 during FF Interview 1 explained that: *"I can now express myself so well that I am easily understood by my learners. Now I can explain concepts clearly and accurately."* Teacher 4 in FGD 3 also explained that: *"I am able to articulate convincingly when teaching because I now know my content better."* Teacher 5 and Teacher 4 above indicated that professional learning influenced their pedagogical practices concerning their classroom communication as they became able to explain concepts clearly, accurately and convincingly which enhanced lesson delivery. Most often, some of the major challenges of mathematics teachers in their teaching roles are clarity and accuracy during instruction. Teacher clarity and accuracy in teaching promote learner understanding and concept formation and the absence of these hampers lesson delivery. The ability to explain content clearly and accurately is in line with theory (Ball et al. 2008) which points to teacher understanding of mathematics content that they teach which enables them to explain concepts clearly and convincingly. When teacher explanations are clear, accurate and convincing, learners tend to trust and develop confidence in their teacher which creates strong learning relationships. Consulted literature (Diloyan 2017) shows that appropriate classroom communication simplifies learning, helps learners to achieve goals and strengthens the connection between learners and teachers. These teachers said new vocabulary, expressions and ideas which they gained through professional learning improved their expression. As well, the improved understanding of concepts influenced their pedagogical practices and created an overall positive experience in the classroom.

Confirming how professional learning influenced classroom interaction in their teaching roles, Teacher 2 during PEI reported that: *"Through interaction with my learners I now interpret learners' non-verbal communication and know whether or not they are understanding what they are learning."* Through their professional learning, some FET Grade 12 mathematics teachers reported influence on their pedagogical practices related to interpreting learners' non-verbal communication. Teachers always need to be alert during instruction to see and interpret different forms of learner communication correctly to capture or influence learner attention and, consequently, knowledge retention. Surveyed literature (Nordquist 2019) shows that non-verbal communication is the use of symbolic signs such as eye contact, facial expressions and gestures by both teachers and learners which provide a signal for progress or lack of it. These symbolic signs and body language were seemingly vital for influencing these teachers' pedagogical practices as they could be more effective than words. Consulted literature (Rawat 2016) shows that body language motivates, inspires and engages learners in learning while it gives the teacher confidence and assures learners that the teacher is competent in the instructional process. Most often the use of memorable body language increases the retention rate among learners as it keeps alive the discussions that accompanied some actions. Thus, professional learning influences recognition of some actions which the teacher may use while emphasising points during instruction as this enhances retention. Surveyed literature (Williamson 2020) indicates identifying learner body language as an important method for teachers to understand and learn from and about their learners. The finding is aligned to theory (Ball et al. 2008) which stipulates that teachers should be able to recognise and understand learners' behaviours in the classroom. Normally, a teacher repeats a point during teaching after observing something among the learners, if it is not just a case of repetition for emphasis.

All the teachers (26) reported that professional learning related to non-verbal communication influenced their formative evaluation during instruction where they found themselves having to change teaching strategies in their pedagogical practices. For example, Teacher 6 during FF Interview 3 reported that: *"Now I use non-verbal communication to decide during the lesson whether to change my teaching strategies and/or the pacing of my lesson."* According to Teacher 6 professional learning regarding non-verbal communication directed operations in the classroom and influenced the pace of instruction. In other words, professional learning influence related to non-verbal communication prompted the teachers' reflection-in-practice. Reflection-in-practice involves thinking about the action while performing the action and immediately taking appropriate action (Mukeredzi et al. 2018). This is particularly important if teachers have to keep on ensuring that they pace lessons appropriately and move with all their learners during instruction. Pacing the lesson generally relates to serious questions teachers ask themselves before and within a lesson regarding time allocation to manage transitions from one activity to another. Consulted literature (Goldsmith 2009: 33) conceives pacing as:

> *The rhythm and timing of classroom activities or units, which includes the way time is allocated to each classroom component and the process of how one decides that it is the right moment to change to another activity or sub-activity.*

Goldsmith's perception shows that professional learning influence on pacing is an integral instructional activity in pedagogical practices which determines the success of a lesson. In this case, Teacher 6 refers to the influence of professional learning on pacing which the teacher adopted as a result of the communication emanating from the learners' reactions and non-verbal expressions, that is, probably the learners' faces complained that the teacher was fast or slow. In this regard, the influence on pacing determines the 'tempo and rhythm' of the lesson where 'tempo' refers to how difficult or easy the content is pitched while 'rhythm' explains how fast or slow a teacher would trade in his/her pedagogical practices within the lesson. It appears as if non-verbal communication indicated whether or not their lessons remained on course during instruction. Referring to learners during a lesson is consistent with the conceptual framework (Cogill 2008) which urges teachers to develop personal mature relationships with learners and present work that interests and motivates them.

Some FET mathematics teachers (17) further explained that professional learning influenced their vocabulary and expression for teaching different content during their pedagogical practices. Regarding this, Teacher 2 during FGD 1 reported that: *"I can now use appropriate vocabulary and expressions in explaining terms and concepts in my teaching because I now understand my learners through our interaction."* Professional learning influenced the teachers' pedagogical practices regarding the use of appropriate vocabulary and expression peculiar to the subject. This influence is aligned to theory (Bell and Gilbert 2005) which promotes personal and professional growth for these teachers in their roles. Often, the use of appropriate vocabulary and expressions in explaining concepts enhances understanding and encourages knowledge retention among learners. Consulted literature (Bosworth 2016) sums it up that improved classroom communication develops connections, cultivates talents and skills and boosts teacher engagements, thereby influencing teachers' pedagogical practices.

From the discussion above, professional learning influenced FET Grade 12 mathematics teachers' pedagogical practices around communication which apparently boosted teacher-learner- interaction. These teachers were able to communicate in verbal and non-verbal ways which enhanced their pedagogical practices. Professional learning was also reported as having influenced the teachers' ability to explain concepts clearly and accurately, articulate convincingly and use appropriate vocabulary and expressions in explaining terms and concepts during their roles. The influence of professional learning, was also reported in interpretation of learner non-verbal communication. The following sub-theme discusses how professional learning of these teachers influenced their collegial communication.

Collegial communication

Collegial communication was another area where FET Grade 12 mathematics teachers' pedagogical practices was influenced by professional learning in teaching roles. Collegial communication in this regard relates to sharing professional or social information among colleagues which teachers reported to have been influenced by professional learning.

Affirming how professional learning influenced collegial communication, Teacher 7 during PEI reported that: *"I used not to communicate with colleagues but now I communicate regularly because of what I professionally learnt from colleagues about content and the challenges I came across in my teaching."* Teacher 7 noted that their professional learning experiences had provided some impetus to communicate as colleagues in their roles. The report indicated that communicating with colleagues presented teachers with opportunities to learn in their pedagogical practices. FET Grade 12 mathematics teachers (15) also confirmed that professional learning influenced their collegial communication which, in turn, is vital for solving each other's problems in their teaching roles. For example, Teacher 3 during FGD 1 said, *"I ask colleagues to help me to work out solutions to some of the challenges I face in my work. I also ask for methods of presenting such challenging questions to learners."* The influence of professional learning regarding asking for help to work out solutions to challenges reported in the quotation above enhances professional growth, job satisfaction and professional commitment critical for these teachers' pedagogical practices in their teaching roles. The teachers' connectivity in their roles is aligned to theory (Ball et al. 2008) which requires teachers to familiarise themselves with the content, pedagogy and structure of their curriculum. Usually, inability to deal with one's challenges at work is frustrating, exhausting and emotionally draining. Thus, through professional learning, these teachers collaborated and provided invaluable support to each other in their teaching roles.

Confirming the influence of professional learning on collegial communication in their teaching roles Teacher 6 in FGD 1 explained: *"I can now share experiences with other teachers. ... Through these teacher associations I also discuss key concepts in different topics to know what to focus on in each topic in my teaching."* Reviewed literature (Clayton 2016) indicates that sharing is an essential skill which builds healthy, strong relationships and contributes to the well-being and happiness of colleagues. Generally, society believes that sharing is caring. Thus, by sharing experiences, the teachers cared for colleagues in their teaching roles. Endorsing the influence of professional learning related to sharing, reviewed literature (Purdy 2018; Zahrzewski 2012; Cook 2017) adds that sharing relationships among teachers help students to do better, as teachers may improve their classroom practice. Collegial communication through sharing experiences, skill, strategies and ideas, reported above, provided FET Grade 12 mathematics teachers with solutions to challenges they faced in their teaching roles. Professional learning influence related to teacher collaboration is consistent with theory (Bell and Gilbert 2005) which emphasises the importance of professional learning in the social domain. Consulted literature (Puncher and Taylor 2006; Palaniandy 2017; Mora-Ruano 2019) argues that collegial communication leads to higher quality instruction which, in turn, increases learner academic achievement through improved pedagogical practices.

How professional learning influenced pedagogical practices related to collegial communication was reported by Teacher 1 during FF Interview 3: *"I am now connected to my friends and we talk to each other anytime to help one another. We collaborate."* Thus, it was through professional learning influence that teachers seemingly connected and networked with one another leading to collaboration in their pedagogical practices. Surveyed literature (Puncher and Taylor 2006; Graham 2017; Mora-Ruano 2019) views teacher collaboration as a force that holds out huge, unprecedented hope for the improvement of teaching in schools. Teacher collaboration can develop networks based on trust and empathy while regular interactions forge lasting professional and mentorship relationships healthy for improved pedagogical practices in their teaching roles. Teacher collaboration is consistent with theory (Bell and Gilbert 2005) which shows that teachers must engage in collaborative professional learning for personal, social and occupational reasons.

In addition, Teacher 11 in FF Interview 3 raised how professional learning influenced their communication with parents in surrounding communities. The participant reported: *"I have improved my relations with the community. I now communicate with parents of the children whom I teach."* Professional learning for this teacher influenced teacher/parent relations as it opened channels of communication between teachers and parents. Consulted literature (Kamra 2017) indicates that teachers must take the values and norms of the communities in which they work into their classrooms if they hope to make a change in those societies. Communicating with communities promotes what theory (Ball et al. 2008) encourages, that teachers should understand their learners' backgrounds and contexts and be able to predict what the learners will find interesting and motivating during instruction. Communicating with parents influences teachers in their teaching roles to engender community aspirations during pedagogical practices and stir development, given that teacher communication becomes vital for classroom practice when it is context-specific. Literature reviewed (Densmore 2010) advises that through communication with their communities, teachers must have knowledge of and cultural sensitivity to their communities which influences how they handle learners during pedagogical practices.

The section above discussed the influence of professional learning on FET Grade 12 mathematics teachers' pedagogical practices related to classroom and collegial communication. In relation to classroom communication professional learning influenced FET Grade 12 teachers to use appropriate vocabulary and expressions in explaining terms and concepts, to better understand their content, use and interpret non-verbal communication, explain concepts clearly and accurately and articulate points convincingly, as well as reflect-in-practice. Professional learning also influenced these FET teachers' collegial communication which gave rise to collaboration and sharing of information and experiences to solve some challenges in pedagogical practices in their teaching roles. Therefore, professional learning significantly influenced the communication of the FET Grade 12 mathematics teachers in their pedagogical practices in their roles. How professional learning influenced these teachers' pedagogical practices regarding managing learner discipline is discussed next.

Managing learner discipline

All the FET Grade 12 mathematics teachers (26) indicated that professional learning through teaching roles influenced how they managed learner discipline during pedagogical practices. Generally, learner discipline in some South African schools is a great concern for teachers (Moyo et al. 2014) in their teaching roles. Consulted literature (Meador 2019) relates learner discipline to a system involving the maintenance of a highly conducive climate for immediate and future learning which includes the use of instructions, rules, policies and practices to manage learner behaviour. In this study, learner discipline is regarded as the maintenance of order in the classroom and the sustenance of acceptable behaviour of learners during pedagogical practices. Thus, learner discipline plays a significant role in allowing the process of learning to take place without disruptions.

Comments from all FET Grade 12 mathematics teachers (26) studied suggested that professional learning influenced their management of learner discipline and behaviour which helped create conducive learning environments in the classrooms. For example, Teacher10 during FF Interview 3 said: *"I can now manage learner discipline and create an orderly environment in the classroom so that learning can take place without unnecessary interference."* Another participant speaking about managing learner discipline said: *"I can now create order in the classroom to have a conducive learning environment. ... I can now manage my learners properly and meet their learning expectations"* (Teacher 6 during FDG

1). The ideas above were shared across all data sources, the FGDs, FF Interviews and PEIs by different teachers. Both Teacher 10 and Teacher 6 concur that professional learning through teaching roles influenced how they managed learner discipline in the classroom. The conduct of learners at the time of this study was one of the prominent factors influencing the classroom learning environment in South African schools. Managing learner discipline in the classroom is about being in control of one's class, making sure that learners abide by the teacher's expectations during instruction. Such a responsibility for teachers is usually at the centre of meaningful and successful teaching and learning whereas lack of it may lead to indiscipline and chaos in their pedagogical practices. Researchers (Giamporcaro and Dhlamini 2017; Rossouw 2003) studying learner discipline in South African secondary schools reiterated that managing learner discipline needs to be afforded first priority in schools as it maintains well-intended efforts to develop a culture of learning among learners. This is consistent with conceptual framework (Cogill 2008) which points out that retaining control in their classrooms is a vital quality for good teaching. Again, the influence of professional learning on the FET Grade 12 mathematics teachers regarding the creation of a conducive learning environment was also raised in the quotes. This related to setting up a platform devoid of physical intimidation and emotional frustration which allowed for a free exchange of ideas and promoted teaching and learning in the classroom. Drawing from conceptual framework (Cogill 2008), creating conducive learning environments allows teachers to create a relaxed and enjoyable atmosphere in the classroom which enhances learner learning and involvement during their teaching roles.

However, one of the participants maintained that it was extremely difficult to manage learner discipline even though the teacher had been exposed to several professional learning opportunities through teaching roles. The participant said: *"It is still not easy to maintain order in class even though we learn about this so often. Learners are undisciplined nowadays."* (Teacher 3 FGD 1). Teacher 3 also indicates that managing learner discipline for some FET Grade 12 mathematics teachers was a challenge to deal with at that time. This observation confirms research (Nene 2013; Rossouw 2003) whose findings revealed that learners were becoming unruly and less respectful than ever before. Disciplinary problems are the most serious challenges for the teacher, and a lack of knowledge and skills in classroom management and discipline control in new and unqualified teachers alike was realised by Mukeredzi (2015). Mukeredzi noted that when teachers possess such knowledge, they are often unable to apply it in their pedagogical practices, instead resorting to practices that they experienced as learners and adopting classroom management techniques that are contrary to their current circumstances. Teachers need skill in creating conducive learning climates that do not pressure them and learners that do not disturb with unnecessary chatter and noise. Reviewed literature (Findley 2011) indicates that managing learner discipline improves the school environment, eliminates fear among learners and teachers, teaches learners self-discipline, encourages great pleasure in learning and promotes individual engagement in learning. Taken together, the findings above concur with theory regarding knowledge of students (Ball et al. 2008) that teachers must understand the needs and characteristics of their learners, as this will help reduce class disciplinary problems.

The influence of professional learning on managing learner discipline realised by FET Grade 12 mathematics teachers gave rise to the development of sympathy and empathy towards learners during pedagogical practices. Participants in FGDs, FF Interviews and PEIs concurred with Teacher 7 who commented: *"Now I am tolerant and patient with my learners considering their background. I can now relate and choose appropriate ways of dealing with their situations"* (Teacher 7 during PEI). These teachers' pedagogical practices seemed to have changed due to professional learning which seemingly made them tolerant and patient. Tolerance is often regarded as the most effective, dependable means of managing learner discipline. Consulted literature (Alyzyoud et. al. 2016: 35) defines tolerance as, "respect, acceptance and appreciation of the rich diversity of our … cultures, our forms of expression and ways of being human."

The definition of tolerance above, suggests that tolerance relates to the best practices in teachers' pedagogical practices which can lead to elimination of conflicts and differences on the basis of respect and understanding of learners' backgrounds. Surveyed literature (Rabb and Freitag 2015) confirms that teachers in schools deal with learners of diverse origins ranging from their cultures, backgrounds and ability levels, hence, the need to embrace tolerance so as to foster 'harmony in difference' in their roles. Drawing from theory (Ball et al 2008) tolerance relates to specialised content knowledge which directs teachers to respond to learners' 'why' questions irrespective of who they are. In essence, tolerance is awareness of oneself in relation to others which is basically a measure of self-discipline. Besides what was highlighted by Teacher 7 above, other connotations of tolerance are forbearance and impartiality, as well as open-mindedness, which are critical to these teachers' pedagogical practices and management of learner discipline. Usually, when learners discover that their teachers are tolerant and patient with them, as alluded to by Teacher 7, that creates mutual relationships between teachers and their learners which promote discipline and, hence, learning. Dealing with learners' situations appropriately, was another form of tolerance in which professional learning had influenced these teachers' pedagogical practices. The teachers explained that dealing with learners' situations created mutual trust between learners and their teachers which enhanced learner discipline.

The discussion regarding the influence of professional learning on FET Grade 12 mathematics teachers' pedagogical practice related to managing learner discipline included creating an orderly classroom environment devoid of unnecessary interference, meeting learners' learning expectations and choosing appropriate ways of dealing with learners' situations and problems. The influence of professional learning regarding creating an orderly learning environment in the classroom enabled these teachers to relate to and deal with situations of their learners appropriately. The FET Grade 12 mathematics teachers reported that professional learning influenced their pedagogical practice around management of learner discipline related to meeting learners' learning expectations which propagated interest and motivation in both teachers and learners to take responsibility for the learning process. The next section discusses how professional learning influenced the way in which FET Grade 12 mathematics teachers managed teaching and learning resources.

Managing teaching and learning resources

14 FET Grade 12 mathematics teachers reported professional learning influence around pedagogical practices in relation to managing teaching and learning resources. Reviewed literature (Ministry of Education, Guyana 2016) indicates that teaching and learning resources are materials teachers use to deliver instruction and support learning. Thus, managing teaching and learning resources entails managing the curriculum policy documents, materials and equipment used in pedagogical practice. More often than not, the teaching and learning process is dependent on how well the teaching and learning resources are used and managed. Theory (Ball et al. 2008) refers to managing teaching and learning resources as having a particular grasp of materials and programmes that serve as "tools of the trade" for teachers. Generally, no teacher can work successfully without tools of the trade, hence, professional learning influenced the FET Grade 12 mathematics teachers' management of teaching and learning resources as critical mediation tools in their pedagogical practices.

Professional learning through teaching roles influenced how FET Grade 12 mathematics teachers (14) organised and managed the curriculum as a teaching resource in their pedagogical practices. Teacher 6 during FGD 2 explained that: "*I can now re-organise and manage the curriculum as a teaching resource so that related topics are taught together in a manner that links related concepts*." Re-organising and managing the curriculum policy document as a teaching resource raised by Teacher 6 in the quotation above is often perceived by teachers as an easy way to promote concept formation in learners during pedagogical practices. Manipulating the organisation and management of content in the curriculum is supported by Hurrell (2013) who emphasises that the teacher is responsible for directing the teaching and learning process towards designed educational ends, purposes and values. In support of these ideas consulted literature (Narayan et al. 2011: 8) emphasises that:

> *It is important for instructors to realize that although a curriculum may be set down for them, it inevitably becomes shaped by them into something personal that reflects their own belief systems, their thoughts, and feelings about both the content of their instruction and their learners.*

Thus, teachers are persuaded to realise that organising and managing the curriculum is indeed central to their teaching roles. Teaching related topics together which was meant to arrange topics such that those whose concepts are interrelated follow each other often promotes concept development on the teaching plan. I consider that re-organising and managing the curriculum in that manner portrays the leadership and management qualities a teacher in the classroom requires to support his/her pedagogical practices. According to the South African Education Policy (DoE 2000), which is in current use, a teacher is an interpreter and designer of learning programmes and materials during pedagogical practices. The policy bestows teachers with the power to select, sequence and pace the learning in a manner that accommodates subject needs and learner differences. In this regard, teachers are leaders, administrators and managers in their roles. Consulted literature (Harrison and Killion 2014; Villegas-Reimers 2009; Bush and Glover 2016) asserts that leadership qualities are helpful to manage and control learners in the classroom, to manage instruction and to support learner learning to improve school success. Hence, professional learning influence on these teachers enhanced their leadership skills to successfully manage the curriculum during pedagogical practices.

The FET Grade 12 mathematics teachers (14) realised professional learning influence around resource management related to curriculum policies in teaching roles. Usually, curriculum implementation is guided and controlled by curriculum policies. Commenting on how professional learning influenced managing curriculum policies Teacher 1 during FGD 2 said: *"I can now implement new marking policy guidelines such as CA (consistency accuracy) marking. I can also implement examination policy guidelines and suggestions from Marker's reports."* All the teachers concurred that they never used to read such documents as examination policy guidelines and marker's reports which they now read due to professional learning. CA marking refers to marking following the logic of the answer in mathematics rather than the prepared marking guide (memorandum). Such marking helps avoid penalising learners due to small errors in their workings, which these teachers reported as a strategy which they had adopted in their pedagogical practices not to discourage learners in their efforts. Drawing from professional learning domains of influence propounded by theory (Bell and Gilbert 2005), teachers should be familiar with policies that relate to their occupational environment. Thus, professional learning influence on FET mathematics teachers' pedagogical practices regarding reading policy documents made these teachers well-informed in their roles.

Managing materials and equipment was one area in which professional learning influenced FET mathematics teachers' pedagogical practices in their roles. One of these teachers reported that: "*I now keep learners' calculators and mathematical instrument sets so that learners do not lose them. I can now account for the text books that I give to learners and have an effective retrieval policy at the end of the year"* (Teacher 9 FF Interview 3). According to Teacher 9, through professional learning the teacher realised the need to keep some materials and equipment to avoid learners losing them which would stifle the instructional processes during pedagogical practices. While keeping these mediational tools may have been vital for instructional processes in the classroom, it probably affected learners who wanted to work ahead of the teacher. Surveyed literature (Blandford 2003) reflects managing teaching and learning resources as a basic role for the teacher in line with the South African Education Policy (2000) which encourages teachers to keep and use media and everyday resources appropriately in their teacher roles. For these teachers, teaching and learning resource management was crucial for the sustenance of pedagogical processes.

Another participant during the focus group discussion added that: *"I now keep an asset register to account for teaching and learning materials and equipment that I keep"* (Teacher 23 during FGD 4). From the response it was through professional learning that FET Grade 12 mathematics Teacher 23 started accounting for teaching and learning materials and equipment through maintenance of an asset register which they had never kept before.

Consulted literature (Shah 2018) defines an asset register as a document where materials and equipment used by teachers and learners are recorded each time they are borrowed. In this case, the asset register helped FET teachers in their teaching roles to account for materials and equipment distributed to learners for use. Reviewed literature (LINQ 2018) foregrounds the importance of keeping an asset register as tracking the condition of assets, their age, financial value, indication of remaining lifetime and, also, to guard against theft. In fact, accounting for materials and equipment distributed to learners is a basic teacher attribute which encourages personal care and responsibility. Some FET Grade 12 mathematics teachers explained that they never kept any asset registers before but through the influence of professional learning in their teaching roles they learnt the valuing of keeping them. Some of the teachers explained that keeping the asset register improved their pedagogical practices as materials and equipment were readily available for learners during instruction. Although Teacher 11 in FGD 4 kept an asset register, he further explained that: *"I keep the asset register but it is a hell lot of a job. It takes a lot of my teaching time."* The negative input regarding keeping asset registers by Teacher 11 suggests that, for some teachers, maintaining the asset register was a policy directive rather than an influence of professional learning. However, it appears that managing the asset register is crucial for teachers' accountability of resources entrusted to them for their pedagogical practices.

In the discussion above, professional learning influenced some FET Grade 12 mathematics teachers' management of teaching and learning resources, such as policy documents, calculators and textbooks, as well as maintenance of asset registers, to enhance easy availability during and for teaching and learning. However, one of the teachers felt that keeping the asset register was time consuming at the expense of the teaching and learning process.

CONCLUSION

This chapter presented and analysed data which addressed the third and last research question which was about the ways in which professional learning influenced FET Grade 12 mathematics teachers' pedagogical practices in teaching roles. From data generated through FGDs, FF Interviews and PEIs the influence of professional learning emerged around four major themes: classroom behaviour; communication; managing learner discipline; and managing teaching and learning resources. Firstly, in relation to classroom behaviour, findings reveal that professional learning influenced FET Grade 12 mathematics teachers as it boosted their confidence, creativity, teaching effectiveness and teaching competence. Enhancement of confidence, creativity, effectiveness and competence improved the pedagogical practices of these teachers in their teaching roles.

Secondly, professional learning influenced FET Grade 12 mathematics teachers' classroom and collegial communication. With regard to classroom communication the FET Grade 12 mathematics teachers were seemingly able to explain concepts clearly and accurately, articulate points convincingly and reflect-in-practice. They became able to interpret learners' non-verbal communication and use interpretations therefrom in their pedagogical practices. Professional learning also gave rise to collegial collaborations and sharing of information and experiences, which some used to solve challenges in pedagogical practices in their teaching roles.

Thirdly, professional learning influenced FET Grade 12 mathematics teachers in relation to managing learner discipline. Regarding managing learner discipline, FET Grade 12 mathematics teachers were able to manage their learner discipline, create an orderly and conducive learning environment without unnecessary interference, be tolerant and patient with their learners and relate and deal with situations of their learners appropriately during their pedagogical practices. However, one of the teachers observed that irrespective of professional learning influence on managing learner discipline, it remained difficult to foster learner discipline nowadays due to the unruly behaviour of learners.

Lastly, professional learning influenced FET Grade 12 mathematics teachers' management of teaching and learning resources in their pedagogical practices. The professional learning influence on managing teaching and learning resources experienced by these teachers included managing policy documents, calculators, textbooks and the asset register. On the whole, professional learning influence on FET Grade 12 mathematics teachers' pedagogical practices seemed to have improved these teachers' classroom practices and promoted the teaching and learning processes in their classroom. Having discussed in detail, the ways in which FET Grade 12 mathematics teachers reported on how professional learning influenced their pedagogical practice in their teaching roles, the next chapter synthesises findings, highlights the contribution of the study and draws recommendations for practice and research.

CHAPTER SEVEN

DISCUSSION, CONCLUSIONS AND SYNTHESIS

Introduction

This study sought to understand FET Grade 12 mathematics teachers' professional learning through teaching roles. Specifically, it sought to establish how they learnt, the kinds of knowledge they gained and how that knowledge influenced their pedagogical practices. The dramatic changes the world is experiencing apparently call for astuteness and alignment to new technologies led by a sound knowledge of mathematics and science. Norris (2012) puts it that mathematics is central to economic development through Science, Technology, Engineering and Mathematics (STEM) industries, hence, the need to focus on how mathematics teachers engage in on-going professional learning in their roles and how the learning influences teaching and learning processes in schools.

The state of mathematics education in post-apartheid South Africa has remained a challenge regarding learner failure rate (Khuzwayo 2000). Studies (Taylor 2012; Spaull 2013) have identified a crisis in mathematics teacher lack of knowledge and competence. In fact, Pournara (2014) indicated appalling mathematics performance where Grade 11 learners were found to be operating at Grade 8-9 level. This has often been blamed on teachers, as studies cited above indicated that mathematics teachers lacked knowledge and skills to deliver the curriculum throughout all the school phases. This was also demonstrated through teachers' inability to compute some of the mathematical problems that they were expected to teach their learners (Spaull 2013). The FET Grade 12 mathematics teachers are always blamed for poor national matric results generally, in particular in the Eastern Cape Province (Taylor 2012, Spaull 2013; Jansen 2012). I chose to study professional learning through teaching roles informed by Billet (2001) and Le Clus (2011) who perceive classrooms, schools and wider professional learning sites as good spaces for teacher professional learning where theory can be linked and tested in practice.

At the time of this study, the Department of Education Provincial and District offices were making stringent efforts to find workable and cost-effective ways of improving mathematics teacher knowledge and skills (DBE 2016) and enhance the teaching and learning of mathematics to meet national development goals. This, therefore, made exploration of how FET Grade 12 mathematics teacher professionally learn in their teaching roles worthwhile.

The study sought to answer one key question: How do FET Grade 12 mathematics teachers professionally learn through their teaching roles and how does the learning influence their practice? To answer this key question, it was vital to unpack it into three subsidiary questions, which needed addressing:

1. How do FET Grade 12 mathematics teachers engage in professional learning through teaching roles?
2. What kinds of professional knowledge do the teachers gain?
3. In what ways do the teachers say their professional learning influences their pedagogical practices?

Answering the above questions would enable the study to explain FET Grade 12 mathematics teachers' professional learning through their teaching roles. The preceding chapters – four, five and six – presented findings addressing these questions. This chapter discusses and synthesises findings explaining how the FET Grade 12 mathematics teachers professionally learnt through their teaching roles. Informed by the findings, using theoretical and conceptual frameworks discussed in Chapter Two of this thesis, the chapter explains professional learning in that light and extracts some lessons for professional learning of FET Grade 12 mathematics teachers in South Africa in general and the teachers studied in particular.

After this introduction, the chapter presents a brief discussion of my reflections on the methodology and theoretical and conceptual frameworks adopted for this study. There follows a review of the study where I outline briefly the chapters contained herein. Findings are then discussed followed by contributions of the study. Lessons and implications of the study are drawn and thereafter a brief conclusion is presented. The subsequent section thus, discusses methodological reflections on this study.

Methodological reflections

Through the interpretive paradigm, my study generated data on and experiences of FET Grade 12 mathematics teachers in their teaching roles. This paradigm enabled me to interact and reason with and benefit from participants through in-depth examination (Berg and Howard 2012) of the different forms of professional learning experienced through teaching roles that FET teachers engaged in, in their settings. In the form of a qualitative inquiry, the study examined widely and deeply (Eyisi 2016) FET Grade 12 mathematics teachers' professional learning through teaching roles and its influence on classroom pedagogical practices. The qualitative approach effectively enabled me to extract rich responses from participants through interaction, and without cohesion (Meo 2010). Although time-consuming, the relaxed atmosphere in which the interviews were held provided for genuine and in-depth discussions with participants. The multi-modal quality of the qualitative approach was useful as I was able to employ FGDs, three-series face-to-face interviews and photo-elicitation to generate multiple types of subjective data to investigate the FET Grade 12 mathematics teachers in particular situations in their natural environments (Christensen et al. 2015): their schools. In this regard, the interpretive paradigm, qualitative approach and interviews were suitable and served well the intentions of the study. However, on reflection, rather than solely depending on these three sources of data, I could have added observation to enable comparisons between interview responses and practice.

The study involved twenty-six FET Grade 12 mathematics teachers in the district of CHE who were teaching Grade 12 mathematics. While the sample was adequate, I felt that I should have accommodated Grade 10 and 11 teachers given that FET embraces Grades 10 – 12 which would have enabled some comparison across grades. Further, while data generation discussions were deeply engaging and analysis immersive, that would probably have yielded different findings, conclusions and recommendations cutting across the three grades. Engaging the same participants in three-series interviews (Seidman 1998) was physically and emotionally draining for me. Reducing the number of interviews to two would probably have helped but again that would mean extending interview time given that each meeting addressed different aspects. Again, a reduced number of interviews might have limited confirming the internal consistency of participants’ stories.

Focus group discussions (FGDs) conducted first instilled confidence in participants for subsequent interviews and enabled explaining to participants about photo- elicitation. Photo-elicitation generated a lot of excitement among participants and the photographs taken were effective for prompting lively discussions. 16 participants successfully did member-checking due to teaching commitments, while 13 listened to the audio recordings which was adequate according to literature. Informed by Candela (2019) and Yin (2014) one may do member-checking with some participants and not all. All the participants who member-checked both transcripts and audio recordings confirmed accuracy of the transcriptions and this allayed my anxieties.

Theoretical reflections

Two theories were identified as lenses for examining how FET Grade 12 mathematics teachers experience professional learning through teaching roles, the knowledge they gain and its influence on their pedagogical practices. I used the Triple lens theory (Fraser et al. 2007) featuring Reid's spheres of action, Bell and Gilbert's (2005) domains of influence and Kennedy's (2005) framework for analysis of continuing professional learning to examine how FET mathematics teachers engage in professional learning through teaching roles.

The triple lens theory through Reid's quadrants helped understand and explain that these teachers engage in professional learning in their formal and informal settings during planned and incidental activities. The domains of influence enabled establishing and explaining that FET Grade 12 mathematics teachers were influenced by their personal, social and occupational aspects to engage in professional learning in their roles. Through Kennedy's framework for analysis in the triple lens theory, I was able to understand and explain that FET Grade 12 mathematics teachers' professional learning encompassed transmissive, transitional and transformative learning in its nature.

The kinds of knowledge professionally gained were analysed through Ball et al.'s (2008) mathematical knowledge for teaching theory (MKT). However, this theory was limited in capturing all the knowledge that the FET teachers experienced from professional learning through teaching roles. The theory tended to enable a narrow exploration of other domains of mathematics teacher knowledge such as general pedagogical knowledge (GPK) and knowledge of learners (KOL) which in my view was a serious omission worth attention. Reflecting on the theory, the inclusion of specialised content knowledge in SMK seemed to undermine teacher specialisation which should distinguish FET Grade 12 mathematics teachers in their roles. I strongly contest this view and think specialised content knowledge must be a separate knowledge domain as this is the knowledge central to making these teachers profession-specific in their practice. In view of these limitations of the theory, I roped in conceptual frameworks (Grossman 1998; Cogill 2008) to understand and analyse other kinds of knowledge that these teachers professionally gained through teaching roles.

Review of the study

This study was about FET Grade 12 mathematics teachers' professional learning through their teaching roles, what they learnt and how the learning influenced their pedagogical practices. The thesis is composed of seven chapters.

Chapter One**:** Chapter One set the scene for the study by examining the problem and its context. The chapter discussed professional learning internationally and regionally drawing from debates on reforms made by different education systems. Locally, the discussion covered how professional learning was promoted and/or failed through the South African policy contexts. This was followed by my personal context and the declaration of my axiological assumptions. The rationale of the study hinged around theory, policy and the availability of literature to which the study sought to contribute. The chapter outlined in brief the triple lens (Fraser et al. 2007) and the mathematical knowledge for teaching (Ball et al. 2008) theoretical frameworks used in the study. This was followed by an overview of the methodological approaches identifying the study as located in the interpretive paradigm: a case study design using a qualitative approach. The chapter ended by wrapping up all these ideas in a conclusion.

Chapter Two**:** This chapter discussed and reviewed relevant literature. The chapter covered debates on professional learning internationally (McDonald 2014; Ball et al. 2005; Villegas-Reimers 2009), regionally (Kyeyune 2011; Komba and Nkumbi 2008; Dougherty et al. 2012) and nationally (Ono and Ferreira 2010; Buthelezi 2012; Chauraya 2013; Ndlovu 2014). Globally, the studies discovered that teachers experienced professional learning through practice, formal education, internships and interaction. Regional literature portrays teacher professional learning as the means to deal with challenges caused by reforms in education and those teachers particularly learn from curriculum change processes. National literature informed that teachers gain professional knowledge from professional learning communities and their practice. This study was carried out to contribute to such professional learning debates around FET Grade 12 mathematics teachers. The study discussed the triple lens (Fraser et al.2007) and the mathematical knowledge for teaching (Ball et al. 2008) theoretical frameworks adopted to unpack and analyse data. The triple lens was used to analyse data addressing the nature of professional learning for FET Grade 12 mathematics teachers. Regarding kinds of knowledge gained and their influences on teacher practices, Ball et al.'s mathematical knowledge for teaching theory was adopted, complemented by conceptual frameworks of Grossman (1998) and Cogill (2008).

Chapter Three**:** This methodology chapter outlined the methods and procedures followed during data generation. This qualitative case study design located within the interpretive paradigm was adopted to capture participants' responses in their natural settings and to elicit their thoughts and opinions on their professional learning (Wyse 2011; Miles et al. 2014; Christensen 2015). A sample of 26 FET Grade 12 mathematics teachers was extracted through purposive sampling. Data generation through FGDs, FF Interviews and PEIs and fifty-two interviews was discussed. A three interview-series (Seidman 1998) approach was adopted. The chapter also discussed data analysis which was accomplished through six steps of open coding. Issues of rigour and trustworthiness, as well as consideration given to ethics throughout the study, were also discussed. The limitations of the study and how they were addressed to minimise impact on findings were also discussed. The chapter described the settings in which data were generated and analysed. The infrastructure, size and nature of the schools in which the study was conducted were discussed with respect to how they influenced professional learning of FET Grade 12 mathematics teachers in their roles.

Chapter Four**:** The chapter presented and analysed data drawing on surveyed literature and the theoretical and conceptual frameworks discussed in Chapter Two responding to research Question One 'How FET Grade 12 mathematics teachers engage in professional learning through teaching roles.' Generally, the FET Grade 12 mathematics teachers experienced professional learning in their teaching roles through two sites: in-school and out-of-school; through practice, formally and informally. It emerged that FET Grade 12 mathematics teachers engaged in professional learning through interaction with colleagues and resources in their roles. It was also discovered that FET mathematics teachers prefer professional learning through hands-on experiences rather than workshops and seminars.

Chapter Five**:** This Chapter presented data and findings on the kinds of professional knowledge that the FET Grade 12 mathematics teachers gained through teaching roles. What emerged is that teachers gain subject matter knowledge, specialised content knowledge, general pedagogical knowledge, pedagogical content knowledge and knowledge of learners. The chapter epitomised Mathematical knowledge for Teaching (MKT) propounded by Ball et al. (2008) as profession-specific for mathematics teachers in their roles. The findings identified additional kinds of knowledge: general pedagogical knowledge and knowledge of learners (Shulman 1987), in addition to those in MKT. As such, the study proposes an additive to MKT to include GPK and knowledge of learners.

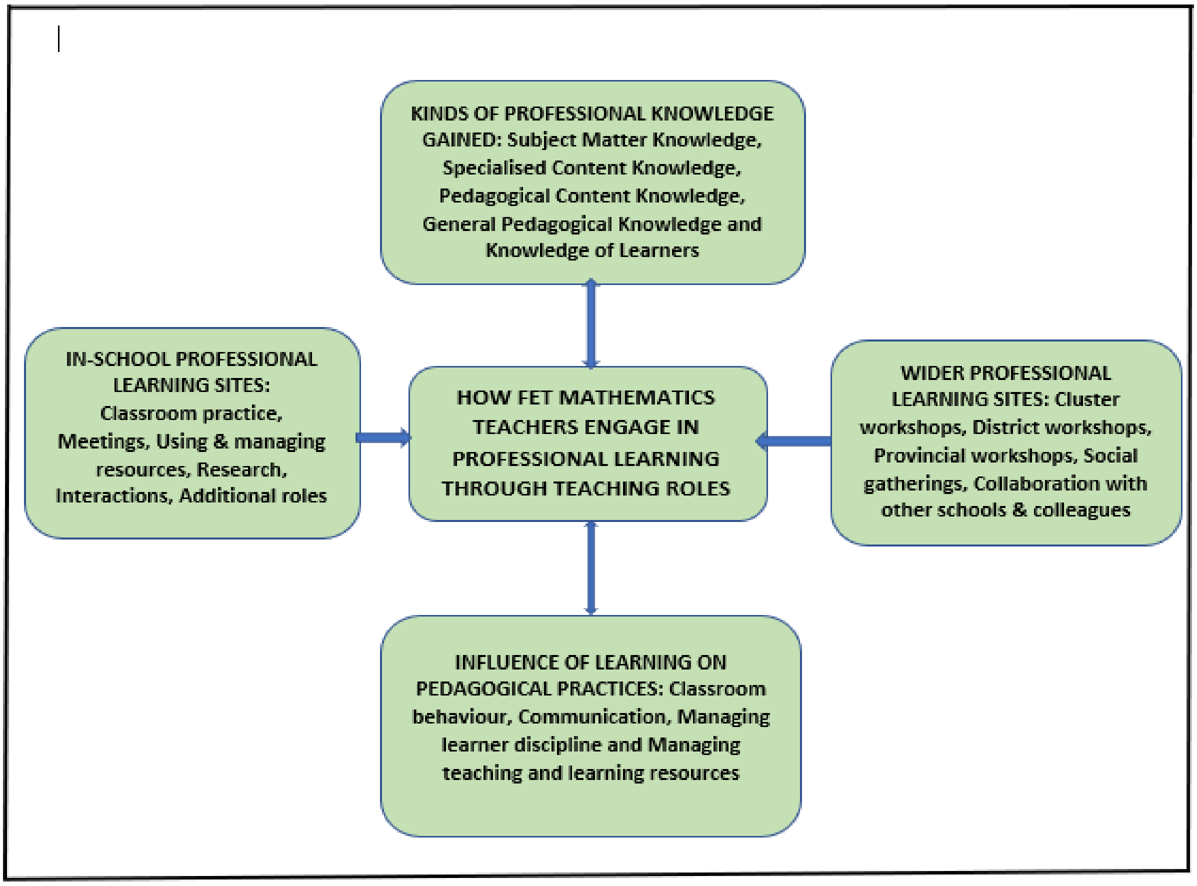
Chapter Six**:** This chapter discussed ways in which professional learning influenced FET Grade 12 mathematics teachers' practices. Professional learning was reported as having influenced their classroom behaviour, communication, management of learner discipline and management of teaching and learning resources. Professional learning influences for these teachers were analysed through Ball et al.'s (2008) MKT theory and Grossman's (1998) conceptual frameworks.

Chapter Seven: This is the final chapter of the study which features methodological and theoretical reflections, as well as discussion of findings for each of the research questions. The chapter further discusses original contributions of this study, as well as implications and recommendations drawn from the study. The following section discusses findings of the study.

DISCUSSION

Firstly, the discussion addresses how FET mathematics teachers engage in professional learning through teaching roles; secondly, the kinds of knowledge they gain; and, thirdly, how the learning influences their pedagogical practices. Figure 7.1 below gives a synopsis of the answers to these questions which will be discussed in detail below.

Figure 7.1: Professional learning through teaching roles



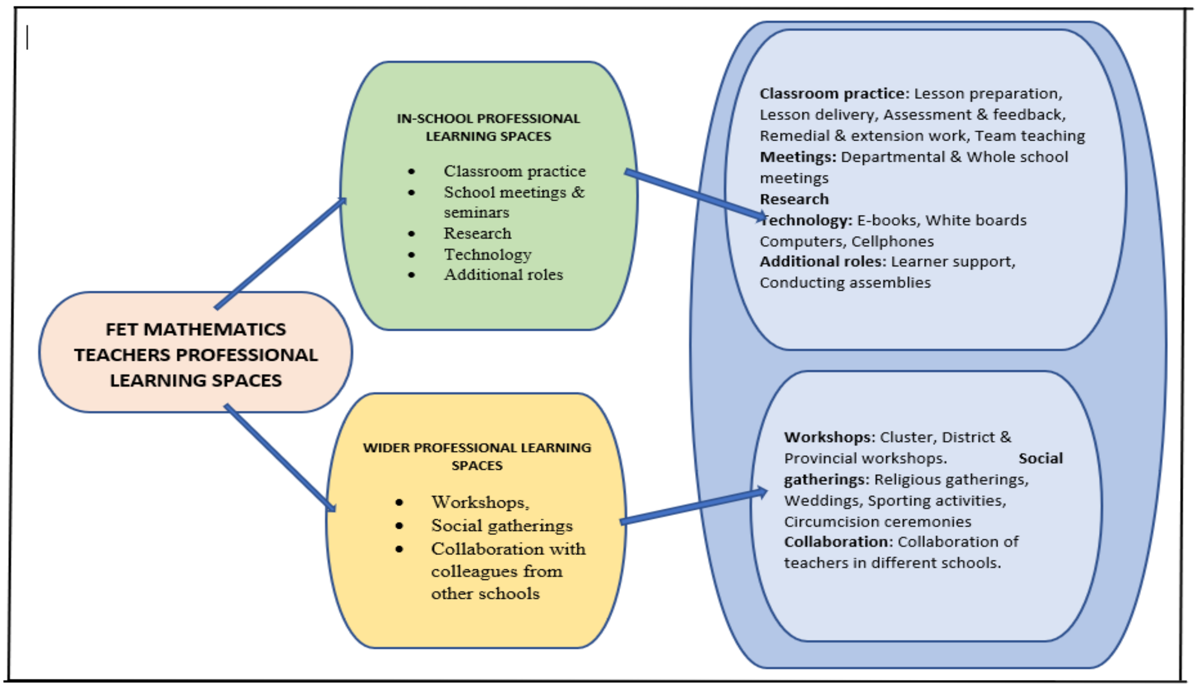
Source: Researcher (2021)

Figure 7.1 indicates FET Grade 12 mathematics teachers' professional learning in their roles which is unpacked question by question below.

How do FET Grade 12 mathematics teachers engage in professional learning through teaching roles?

Findings indicate that FET Grade 12 mathematics teachers engaged in professional learning in two sites: in-school and out-of-school, as shown in Figure 7.1. Within school sites, the teachers experienced professional learning in the informal sphere through teaching roles in classroom practice, non-formally through school meetings and seminars, through research, use of technological sources and performing additional roles. In wider professional learning sites, the teachers engaged in professional learning through workshops, social gatherings and informally through collaboration with colleagues in other schools. These findings were generally consistent with Reid's spheres of action (Fraser et al. 2007) which stipulates that continuing teacher professional learning occurs within formal and informal contexts as planned or incidental. Figure 7.2 summarises the answer to this particular question.

Figure 7.2: FET Grade 12 mathematics teacher professional learning spaces within school and wider professional sites.



Source: Researcher (2021)

Figure 7.2 shows that FET Grade 12 mathematics teachers' professional learning spaces were both through in-school and out-of-school activities. It further illustrates that from the activities in and outside school the teachers experienced professional learning through their involvement and participation in the call of duty within their roles. Subsequent discussion further unpacks Figure 7.2 commencing with how the FET Grade 12 mathematics teachers engaged in professional learning within school professional learning sites.

In-school professional learning

Findings show that FET Grade 12 mathematics teacher professional learning within school contexts occurred in the spaces reflected in Figure 7.2. The discussion commences with professional learning through classroom practice.

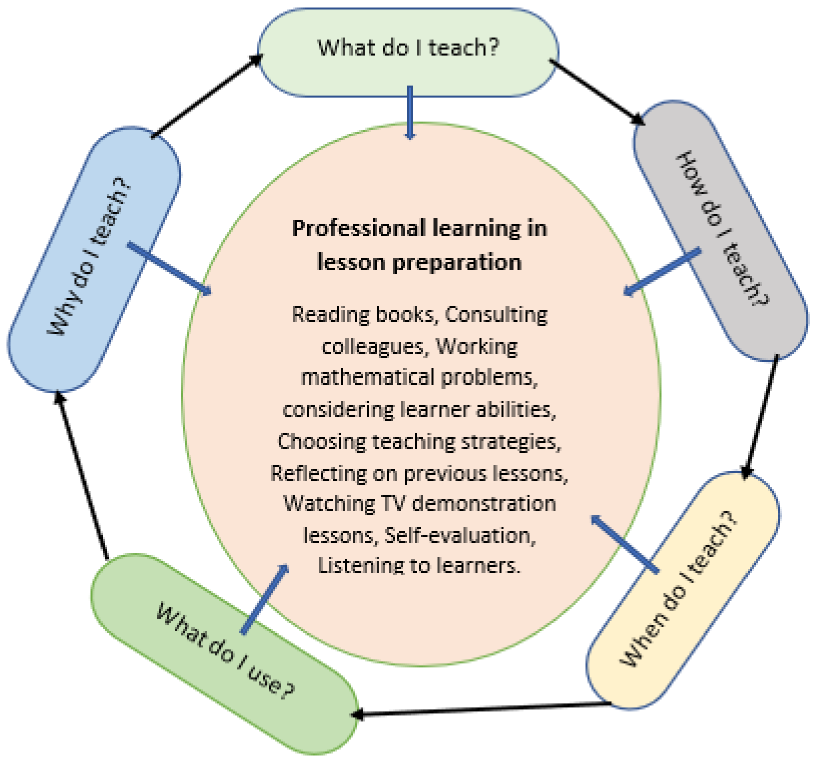
Professional learning through classroom practice

Classroom practice emerged as a major space for FET Grade 12 mathematics teacher professional learning through their teaching roles within their schools. Findings indicated that the FET Grade12 mathematics teachers engaged in professional learning in lesson preparation, lesson delivery, assessment and feedback, remedial and extension work, classroom management, research and team teaching. Drawing on the Triple lens theory (Fraser et al 2007) professional learning in this context occurs in Reid's informal planned spheres of action influenced by these teachers' personal, social and occupational needs. The findings indicated that professional learning was through individual involvement and practice, their own actions and those of others as they formally executed their duties and informally reflected on their work. This kind of hands-on experience portrays teaching and learning for understanding, which can be an effective way of professional learning (Clercq and Phiri 2013). It is through this process of doing the teaching that teachers grow and develop as people and acquire requisite skills and professional attributes to become effective teachers through the transitional, transmissive and transformative (Fraser et al 2007) nature of learning. This is consistent with literature (Villegas-Reimers 2003: 13) which views teachers as, "active learners who are engaged in the concrete task of teaching" from which they improve their professional skills and knowledge. FET teachers also experienced professional learning from lesson preparation.

Lesson preparation

Research findings revealed that lesson preparation engaged teachers in thinking processes that gave rise to professional learning. Lesson planning which is again in the informal sphere of teacher learning (Fraser et al. 2007) prompted thinking about the 'what', 'when', 'how' and 'why' of their intentions in a lesson. Literature (Lim, Barnes and Palmquist 2019) confirms that lesson preparation requires careful mathematics teacher advance thinking to develop a sequential arrangement for the lesson. Figure 7.3 below illustrates how teachers engaged in thought processes and experienced professional learning during lesson preparation.

Figure 7.3: FET mathematics teacher professional learning through Lesson Preparation



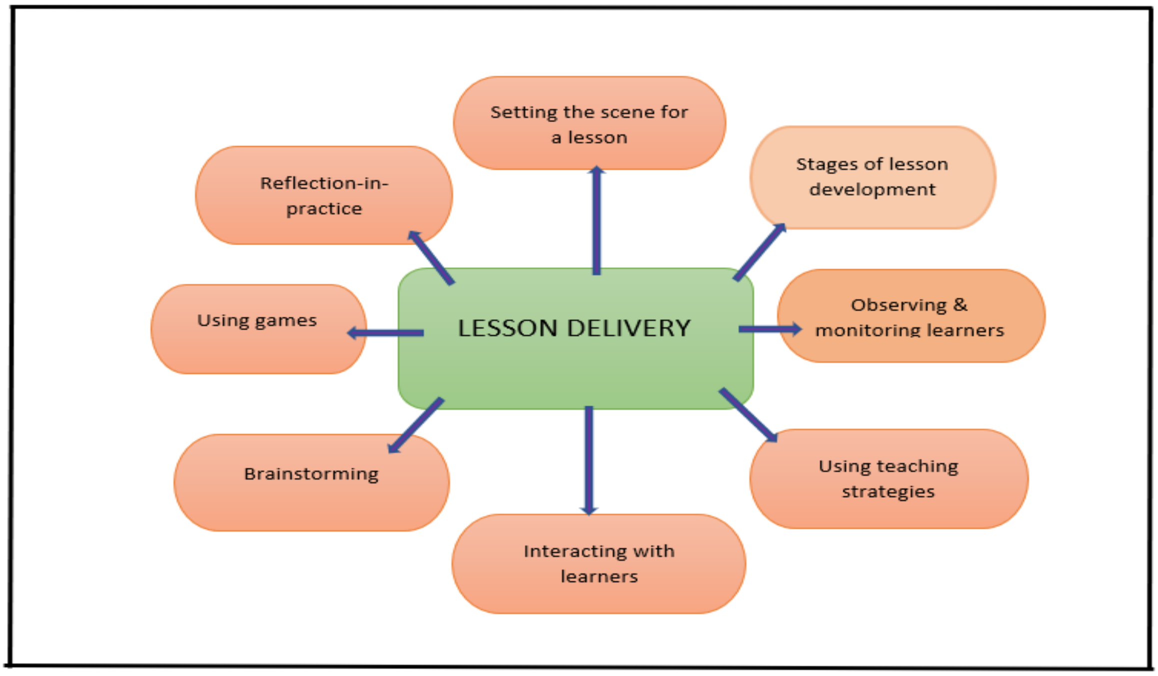
Source: Researcher (2021)

From Figure 7.3 lesson preparation was thought provoking for these FET Grade 12 mathematics teachers as it prompted professional learning through answering the requisite questions. Research findings indicated that the teachers experienced professional learning from reading books, consulting colleagues on some aspects of their work, working out mathematical problems, considering learner abilities and choosing teaching strategies. Literature surveyed (Mukeredzi 2013: 97) concludes that planning enables thorough preparation and increases teacher efficiency and confidence through “self-interrogating, stepping back, ‘pre-playing’ and pre-evaluating classroom practices, and teachers, consequently, develop new knowledge and beliefs on content, pedagogy and student learning”. These processes promote teacher professional learning through the transitional and transformative nature of learning (Fraser et al. 2007). From the findings, this occupational domain which encompassed both personal and social (Fraser et al. 2007) aspects of their learning prompted the teachers’ professional learning through reflecting on previous lessons, self-evaluating, watching television demonstration lessons, planning together with colleagues and listening to learners’ suggestions. In view of these findings, lesson preparation apparently searches a teacher’s mind and directs their practice. This process, therefore, becomes enriching and nourishes their professional growth and confidence as teachers understand their content and processes of instruction before lesson execution. Literature (Mukeredzi 2017; Hill et al. 2008; Hurrell 2013) also shows that consultations with various sources, particularly with colleagues in lesson preparation, are critical as teachers take note and learn from what colleagues consider important. The findings are consistent with theory (Frazer et al. 2007) which advocates for teacher transformative learning through lesson preparation. FET Grade 12 mathematics teachers also realised professional learning in lesson delivery.

Lesson delivery

Research findings around lesson delivery indicated that FET Grade 12 mathematics teachers experienced professional learning through facilitation of learning. The various stages of lesson delivery that enabled professional learning are illustrated in Figure 7.4 below.

Figure 7.4: Professional learning through lesson delivery



Source: Researcher (2021)

From Figure 7.4 professional learning occurred in setting the scene for a lesson, taking the lesson through different stages of lesson development, using different teaching strategies, observing and monitoring learners, interacting with learners, brainstorming, using games and reflecting in practice. Drawing from the triple lens theory (Fraser et al. 2007), in particular Reid's quadrants, professional learning in lesson delivery occurs in the informal space of FET Grade 12 mathematics teacher professional learning. From these findings, teachers must be flexible, astute and apt in every step during instruction and be able to reflect in practice (Mukeredzi 2015) and take immediate action to ensure effective learning. Literature (Cox 2013: Perks 2012) shows lesson delivery as an art and a dual responsibility where both teachers and learners are learners through processes of instruction adopted. These findings relate to theory insofar as teachers must transmit (Kennedy 2005) content through creative, interesting lessons encompassing learners learning needs and expectations. Based on the findings, professional learning through lesson delivery enhanced teacher personal attributes of good teaching, an understanding of what works and what does not and an awareness of their learners learning and achievements. The FET Grade 12 mathematics teachers also experienced professional learning through assessment and feedback.

Assessment and feedback

Findings revealed that assessment and feedback offered the teachers studied professional learning through administered tests, assignments, quizzes and examinations, analysis of learner achievements, developing feedback and evaluation of teaching and learning processes and materials. From the findings, assessment and feedback were indisputable sources of professional learning in the formal sphere of action (Reid's quadrants) prompted by personal and occupational domains (Fraser et al. 2007). From literature (Jepson and Walker 2019) assessment serves as an investigative tool for the teacher to find out as much as they can about what their learners know and can do and what confusions, preconceptions or gaps they might have that guide instruction and individualise learning for learners. In other words, well-designed, data-driven assessments provide valuable feedback, allowing teachers to plan effective lessons which ensure that all learners are learning and have moved to their zone of proximal development. Professional learning in assessment occurs as teachers reflect on both learners and their performance and take appropriate remedial action. Mukeredzi and Nyachowe (2018) point out that such competence takes teachers from assessment of learning, through assessment for learning, to assessment as learning which promotes their professional learning.

An important dimension of their assessment was provision of detailed feedback to clarify students' performance efforts. Feedback is a powerful influence on achievement. The teachers' comments indicate strengths/weaknesses, adding to students' knowledge of the topic, then compile mark profiles and rate students' performance. Mukeredzi & Nyachowe add that students need knowledge of how well they are performing as knowledge of good performance gives them a sense of worth which breathes vigour into them. Similarly, students should also know when they make mistakes so that they learn from them and take corrective measures. Hence, honest and objective feedback places them on the right path to their goal. The findings suggest that assessment shaped teacher classroom practice through re-structuring and re-organising subsequent teaching and learning, which process enabled professional learning. This is consistent with theory (Frazer et al. 2007) which urges teachers to professionally learn through transformative practices and, in the process, transform their learners. In this study, assessment gave rise to remedial and extension work which also promoted the FET Grade 12 mathematics professional learning.

Remedial and extension work

Findings indicate that from remedial and extension work FET Grade 12 mathematics teachers experienced professional learning through identifying learners' learning problems, designing remedial and extension programmes, teaching from concrete to abstract, recognising talent and handling learner diversity. This suggests professional learning in the formal sphere of action, from the occupational and social domains of influence as informed by the triple lens theory (Fraser et al. 2007). From the findings, remedial work demanded teacher creativity and innovation, hence, professional learning through identification of the gap between what learners knew and what they were expected to know. Engagement in remedial and extension work, stretches the teacher to further look into what can be done more or differently to enhance learning thereby promoting professional learning. Literature (Kumar 2016; Cliath 2017; Guerriero 2017) confirming these findings indicates that remedial and extension work requires wide reading and consultations with colleagues, which yields professional learning through increased levels of competence among teachers. Developing appropriate extension tasks which provide more or different forms of practice to extend learners' minds and make learning more meaningful, as learners have a chance to personalise content, promoted professional learning for these FET Grade 12 teachers. These teachers also experienced professional learning in their roles through classroom management as discussed below.

Classroom management

The findings indicated professional learning through classroom management encompassing managing learner discipline, caring for learners, monitoring learners, creating conducive learning environments, enforcing classroom rules and ensuring appropriate sitting arrangements. From the theoretical lens (Fraser et al 2007), classroom management represents a formal professional learning space in the occupational domain of influence. These findings projected classroom management as powerful for professional learning as teachers influenced learners to focus on their learning. From the findings, creating conducive learning environments in classrooms, challenging learners to commit themselves to learning, engaged these teachers in professional learning in setting the scene for effective learning. The findings also portrayed teachers as having experienced professional learning through control of classroom learner behaviour to enhance learner learning levels. Skill and knowledge of how to handle diverse classes with diverse learner ability levels and backgrounds, to inspire, motivate and uphold attention are some of the capabilities that teachers experienced in classroom management and learner discipline, which consequently offered them professional learning. Research confirms that knowledge and skills of classroom management, control and learner discipline, as well as good communication skills enhance classroom practices and professional learning (Chanakya 2015; Mukeredzi 2013). These scholars claim that effective classroom management has the noble reason of doing all of the things that a teacher does to organise students, space, time and materials so that instruction in content and student learning can take place by fostering student involvement and cooperation in all classroom activities and establishing a productive working environment. Literature (Corwin 2019; Marzano et al. 2019; Wiley 2014; Fulton 2018) concurs with these findings explaining that classroom management encourages learning without disturbance. Teachers need professional skills for creating conducive learning climates that do not pressure them, and learners that do not disturb with unnecessary chatter and noise. However, some of the FET Grade 12 mathematics teachers reported continued failure to manage learner discipline in their classrooms citing character decay among learners. Consistent with these findings, Mukeredzi (2013) discovered that classroom management disciplinary problems are the most serious challenges for many teachers and that both novice and experienced teachers alike lacked knowledge and skills for managing and controlling learners. Often when teachers possess such knowledge, they are unable to apply it in practice but resort to practices they experienced as learners or adopt classroom management techniques that are contrary to what they learnt at college or university. Notwithstanding these challenges, professional learning in classroom management remains basic and indispensable for teachers to realise their intended instructional goals. The next section discusses professional learning through team teaching.

Team teaching

From the findings, professional learning also emerged through team teaching and collaboration. Sharing teaching loads both in full or in part and maintaining vertical and horizontal relations, facilitated professional learning in a variety of ways for these FET Grade 12 mathematics teachers. They were able to take note of colleagues' styles of teaching, management of learners during instruction and responses to learner questions and see how other teachers explained concepts better than them which offered them professional learning. In this regard, team teaching offered on the spot learning through comparing one's ways of doing things and those of others in their roles. Drawing on the triple lens (Frazer et al. 2007), team teaching offers professional learning in the formal and informal sphere, influenced by the social and occupational domains. However, some teachers expressed reservations about team-teaching citing fear of exposing their professional shortcomings. Mukeredzi (2015) found that teachers who were totally opposed to team teaching identified, among other reasons, risk of humiliation and discouragement at possible failures, unwillingness to share the spotlight or their pet ideas, fear of losing total control and more demands on time and energy. Others appeared to possess rigid personality types or were wedded to their single methods. However, literature (Goetz 2000; Hargett et al. 2018; Krutka 2016) considers team teaching as a cooperative engagement where teachers complement each other in teaching the same group of learners and, at the same time, learn with and from one another. Participants indicated that team teaching helped them to close gaps between what others did and what they did in their teaching roles which encouraged teachers to foster uniformity and ensure effectiveness in facilitating learning. This ability and confidence to expose one's limitations has been hailed as vital for professional learning. Professional learning through meetings also offered professional learning.

Professional learning through school meetings and seminars

Research findings regarding professional learning through school meetings and seminars indicated that these offered other within-school professional learning opportunities. From the triple lens theory, this was consistent with occupational and social domains of influence as teachers engaged in discussions. From Reid's quadrants in the triple lens theory (Fraser et al. 2007) school meetings and seminars were predominantly within the formal sphere as the meetings were scheduled and structured and had a facilitator. The FET Grade 12 mathematics teachers experienced professional learning through interaction and debate in departmental meetings, and whole school meetings.

Subject specialisation meetings

Mathematics departmental meetings and seminars, coded as subject specialisation meetings, emerged as effective in-school spaces for professional learning within teaching roles. Findings indicated that the FET Grade 12 mathematics teachers experienced professional learning from discussions around content, pedagogy and assessments and from joint planning. Meetings within subject specialisation promoted professional learning through discussions that encompassed expectations, requirements, teaching and policy. Such engagements with specialisation colleagues foster professional learning through dialogue and debate, questioning and observing them, appraisal of own and others' practices overtly or covertly (Mukeredzi and Nyachowe, 2018). Again, incidental subject and other dialogues within specialisation meetings promoted acquisition of professional knowledge and skills of an active nature as they reflected on what they heard, saw and practiced. These joint reflections and feedback involved reviewing a variety of issues and processes in their teaching roles which promoted professional learning. Reflection has been hailed as critical for professional learning (Distard et al. 2004) as it describes an attitude of the mind. Collegial specialisation sharing implies elements critical for teacher learning by not being dictated to but enabled to engage in interaction, with ample occasions for discussion, questioning, critiquing, evaluating, agreeing and disagreeing and being treated and treating each other like professionals (Mukeredzi, 2013). The practices promote development of lifelong collaborative engagements which they (as teachers) themselves direct and on which an ongoing part of their professionalism will be built. Collective learning on an equal echelon through conversations about their practice in their roles provided a strong aspect of their professional learning. Informed by theory, the nature of the FET Grade 12 mathematics teacher learning was in the formal sphere and occurred through interaction and debate, coordinated by a facilitator (Fraser et al. 2007). Further literature surveyed (Guskey 2009) emphasises teacher engagement in school meetings and workshops to help one another to cope with curricular and instructional challenges in the classroom. Findings also revealed whole school meetings as having fostered FET Grade 12 mathematics teachers' professional learning.

Whole school meetings

Whole school meetings emerged as another formal sphere (Fraser et al. 2007) in which professional learning of FET Grade 12 mathematics teachers occurred from deliberations and discussions. The findings around whole school meetings from which the FET Grade 12 mathematics teachers experienced professional learning indicated that they brought teachers together for a common good: effective learning by their learners. This is echoed in literature (Mukeredzi 2009) which conceives whole school meetings from where teachers experience professional learning as a factor that not only breaks departmental boundaries but also encourages interdepartmental interdependence in schools. However, some of the teachers studied expressed sentiments that whole school meetings were sometimes unproductive. Clifford (2019) found that whole school staff meetings are sometimes dominated by principals who are always at the front running through a bullet point list to which some teachers in the background would be murmuring discontent with conversations erupting in disapproval from senior staff. Such meetings tend not to benefit teachers due to their transmissive nature (Fraser et al. 2008) but to build a negative attitude towards meetings among teachers. Contrarily, Mukeredzi (2009) found that whole school meetings benefitted teachers as they focused on methods of enquiry and learning, thinking deeply about their learners' learning, and examining their work from a global whole school perspective. Such inclusive meetings enable professional learning through what is happening elsewhere which fosters both collegial and individual professional learning. Research also emerged as a space through which FET Grade 12 mathematics teachers realised professional learning.

Professional learning through research

Findings indicated that FET Grade 12 mathematics teachers' professional learning through research was prompted by using technological resources. The use of informal spheres of action (Fraser et al. 2007) such as e-books, whiteboard, television sets, cellphones and the internet emerged as effective technological platforms for FET Grade 12 mathematics teachers' professional learning through research. The use of technological sources promoted teacher access to information and connected them to other people, data, resources and expertise, which offered invaluable professional learning in the social domain (Bell and Gilbert 2005). Literature (Kendall 2019) contends that the use of technological resources empowers and inspires teachers to effectively teach their learners drawing on information obtained therefrom. Further, watching and sharing experiences on television emerged as a powerful tool for professional learning from where they gained learning from demonstration lessons. Usually, demonstration lessons on television are effectively delivered from which teachers can professionally learn. The technological resources had the power to attract teachers to observe best practices on television through which they experienced professional learning in both the personal and occupational domain (Fraser et al. 2007).

Findings further indicated that professional learning also occurred as the teachers perused the internet, accessing, downloading and printing information from on-line communication networks. In addition, the use of power-point for lesson presentations by other teachers created an avenue for professional learning within the school sites. These findings show that

FET Grade 12 mathematics teachers were professionally learning and embracing new technologies and moving into the digital era as they attempted to replace traditional ‘chalk and talk’. What emerges from the section above is that professional learning through research occurred informally in the personal, social and occupational domains of influence and learning was transitional (Fraser et al. 2007).

Professional learning through additional roles

Professional learning was also experienced through additional roles by six of the FET Grade 12 mathematics teachers studied, who held posts of responsibility in their teaching roles. Such teachers experienced professional learning through participation in co-curricular and administrative roles which are discussed below.

Co-curricular roles

Findings indicated that professional learning through co-curricular roles were experienced from coaching learners in different sporting disciplines, communicating with them and reflecting on their attributes. Based on the findings, professional learning from co-curricular activities for these FET Grade 12 mathematics teachers emerged as developing a better understanding of learners and learner behaviour making connections with classroom instruction. In view of theory (Fraser et al. 2007), this was professional learning in the informal sphere of action (Reid’s quadrants) and within the occupational domain of influence (Bell and Gilbert 2005). Literature (Leung et al. 2011) discovered that success for teachers in their instructional roles depends on whether they are able to connect socially and academically which co-curricular activities offer them, as they assume responsible positions as leaders, guides and mentors to their learners and other teachers. Thus, co-curricular roles were professional learning spaces which had the capacity to influence classroom organisation and interactions in the transitional and transformative (Fraser et al. 2007) mode.

Administrative roles

With regard to administrative roles the said FET Grade 12 mathematics teachers experienced professional learning through participation in school management teams, conducting school assemblies, organising learners for devotions and providing learner counselling support. Findings show that teachers realised professional learning through decision-making, provision of guidance to both teachers and learners, creating conducive organisational cultures and coordination of effective instructional processes in the school. In line with theory (Fraser et al. 2007), professional learning in this regard was in the formal and occupational spheres. Findings on additional roles show that professional learning revolved around leadership and management. Informed by literature (Bredeson and Johansson 2006), teachers are both instructional leaders and learners in their roles. Hence, administrative roles enabled teachers to provide conditions under which instructional roles would meet set goals.

The section above has indicated that the nature of professional learning of FET Grade 12 mathematics teachers within the school site was in both formal and informal spheres and prompted by the personal, social and occupational domains of influence in their roles (Fraser et al. 2007). FET Grade 12 mathematics teachers experienced professional learning in transmissive, transformative and transitional ways (Fraser et al. 2007) through practice and interaction with colleagues, learners and materials in their roles. The next section discusses professional learning in wider professional learning sites.

Professional learning in wider professional learning sites

Findings indicated that FET Grade 12 mathematics teachers experienced professional learning through workshops, collaboration with teachers from other schools and social gatherings. The nature of professional learning in each of these learning spaces is discussed in the next section, starting with workshops.

Professional learning through workshops

Findings indicated that the FET Grade 12 mathematics teachers experienced professional learning through provincial, district and cluster workshops. Professional learning in these spheres was generally 'transmissive' as the activities were structured, organised and delivered by experts – 'expert tuition' (Fraser et al. 2007) – and broadly focused on technical aspects of the job rather than issues relating to values, beliefs and attitudes (Kennedy 2005). Through provincial, district and cluster workshops, professional learning occurred through planning meetings, centralised marking and moderation, discussions of curriculum, policy changes and content. Thus, professional learning occurred in the formal sphere delivered by subject planners, subject advisors and cluster leaders. The findings were consistent with Bell and Gilbert's (2005) framework where the impetus originated from the occupational domain as all activities were organised and planned to satisfy teachers' technical aspects of their teaching roles. As in whole-school meetings above, the workshops were generally disliked as many teachers felt pressured to attend. However, literature (Sayed 2016) emphasises professional learning through workshops as valuable for improving teacher comfort levels with content challenges and at the same time enhances adjusting their working cultures in their schools. Literature further indicates that workshops develop teacher connections and interactions which encourages extension of subject matter knowledge and improved teaching practices. However, other literature (Jita and Mokhele 2014; Graven 2002; Mukeredzi 2013) criticises one-day workshops as ineffective for teacher professional learning and unable to translate into changes in teacher classroom practices. Notwithstanding that workshops are generally transmissive, transitional and sometimes transformational (Kennedy 2005), and that the FET teachers in this study reported lack of motivation to attend, attendance offered them professional learning.

Sharing experiences and good practices

From the findings FET Grade 12 mathematics teachers also experienced professional learning through interaction about their practice and circumstances at their work places. Findings indicate that professional learning regarding sharing experiences and good practices occurred through informal and incidental collegial interactions like teacher corridor conversations, chats on the bus, at the shops, on the sports field and other such spaces. These informal professional discussions promoted sharing best practices through seeking and offering solutions and advice concerning these teachers' challenges and problems at work. The professional learning occurred in the informal sphere of action (Reid's quadrants) and was influenced by personal, social and occupational domains (Fraser et al. 2007). Such engagements prompted reflection on their own practice and consequently they learnt from both own reflection and others' practices and experiences in their roles. This is supported by literature (Vrieling 2018; Claibome 2019) which indicates that professional learning enables teachers to share and reflect on advice for the improvement of practice and goal attainment in their roles. Sharing experiences and good practices facilitates checking against bias in self-reporting and self-evaluation and also enables class or school-to-school classroom practice comparisons, while at the same time this enables building successful partnerships (Cowan et al. 2016). While such interactions foster professional learning, they occur naturally and individuals themselves may not be aware that they are contributing to their learning (Mukeredzi 2009). Arguments in literature (Langveld 2016; Jones and Dexter 2014) show that professional learning through informal collegial interactions is becoming prevalent and very important as they enhance teacher morale and growth. It is, thus, clear that for the FET Grade 12 mathematics teachers, professional learning occurred anywhere they met as they collaborated as colleagues.

Professional learning through social gatherings

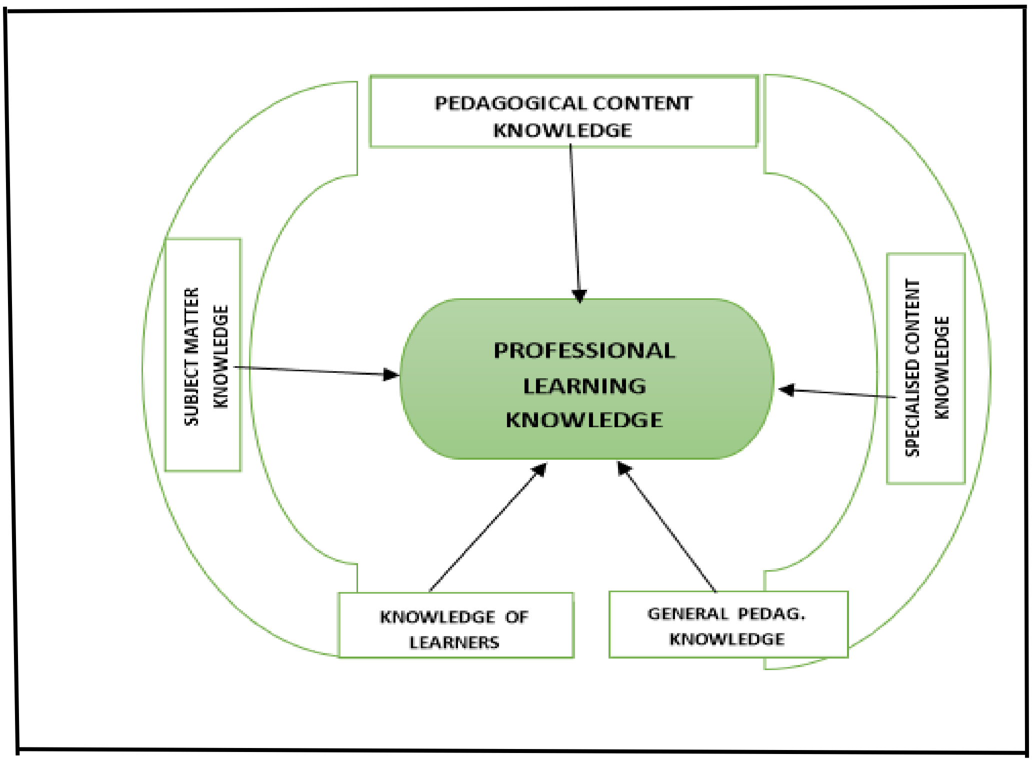
Findings also revealed professional learning through social gatherings like watching sporting activities, religious gatherings, weddings, and community functions as significant for the learning of FET Grade 12 mathematics teachers in their roles. Professional learning emerged from informal spontaneous discussions during fellowship. Indications are that these professional learning spaces were sources of collective wisdom and the establishment of social connections which promoted unity and a sense of belonging and becoming for these teachers (Harfitt 2018). Through these community involvement spaces, FET Grade 12 mathematics teachers experienced professional learning through participation, as well as during parent-teacher meetings. Findings portray that these teachers' professional learning revolved around coaching issues, leadership and socialisation. Community involvement empowers teachers in their roles with an understanding of the environment within which they work which enhances their space awareness in their practices (Preston 2018; Diloyan 2017). From the triple lens framework (Fraser et al. 2007), these were informal spheres of action where the FET mathematics teachers professionally learnt in the social domain of influence and the learning was transitional and transformative.

From this study, professional learning for FET Grade 12 mathematics teachers outside their schools occurred on platforms where teachers met as colleagues or with stakeholders in education. The nature of professional learning in these spaces was a combination of planned, informal and incidental learning while the learning was mostly transitional and transformative (Fraser et al. 2007). Teachers engaged in professional learning motivated by their personal, social and occupational (Bell and Gilbert 2005) needs in their roles. The next section discusses findings related to the second research question.

What kinds of professional knowledge do these teachers (FET Grade 12 mathematics) teachers gain (through teacher roles)?

This second research question on the kinds of knowledge FET Grade 12 mathematics teachers gained from their professional learning through teaching roles identified five domains of knowledge: subject matter knowledge (SMK); specialised content knowledge (SCK); general pedagogical knowledge (GPK); pedagogical content knowledge (PCK); and knowledge of learners (KOL). These findings are represented in Figure 7.5 below.

Figure 7.5: Kinds of professional knowledge gained

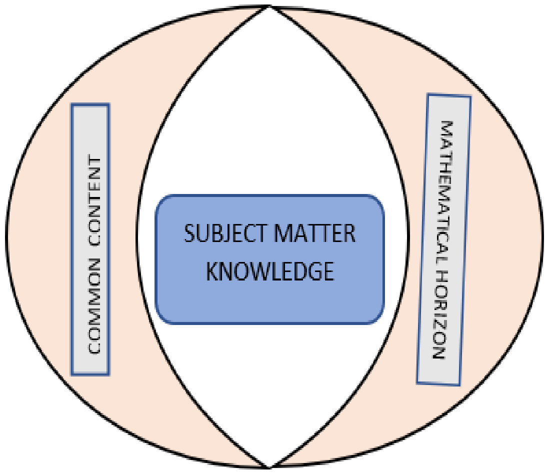


Source: Researcher (2021)

The five different kinds of professional knowledge shown in Figure 7.5 above are equally important for mathematics teachers in their roles regardless of their position and size in the diagram. They complement each other when teachers apply them in classroom practice. This section discusses these findings starting with SMK.

Subject matter knowledge (SMK)

Figure 7.6: Kinds of Subject Matter Knowledge gained



Source: Researcher (2021)

SMK represented in Figure 7.6 above is the content FET Grade 12 mathematics teachers need to know which is not specifically what they teach their learners, as well as the applied mathematics for use in life. From the findings this kind of professional knowledge was gained in two different forms as shown in Figure 7.6: common content knowledge and knowledge at the mathematical horizon. This finding is consistent with theory (Ball et al. 2008) which identifies SMK as composed of common content knowledge, knowledge at the mathematical horizon and specialised content knowledge. However, emphasis from the findings regarding specialised content knowledge (SCK) separates it from SMK, hence, SCK was treated as a separate knowledge domain in this discussion. SMK is discussed as common content knowledge and knowledge at the mathematical horizon.

Common content knowledge

From the findings common content knowledge was experienced as widely used mathematical knowledge which is not necessarily peculiar to mathematics teachers though vital for them. The knowledge emerged as mathematical knowledge related to shapes, sequences, functions, equations, constructions, statistics and probability. Considered together, these findings were related to FET Grade 12 mathematics content which FET Grade 12 mathematics teachers needed for their teaching and which their learners need to learn. According to theory (Ball et al. 2008) SMK in the form of common content knowledge links mathematics facts and concepts to operations in life. Literature (Zeichner 2016; Heggart 2016; Wineburg 2015) also indicates that SMK through common content knowledge is useful to mathematics teachers as it is needed for teaching, recognising inaccuracies, distinguishing between correct and incorrect answers and using mathematical terms correctly. To sum up, common content knowledge which the teachers gained is SMK, which is indispensable for FET Grade 12 mathematics teachers as it is the material that they have to teach.

Knowledge at the mathematical horizon

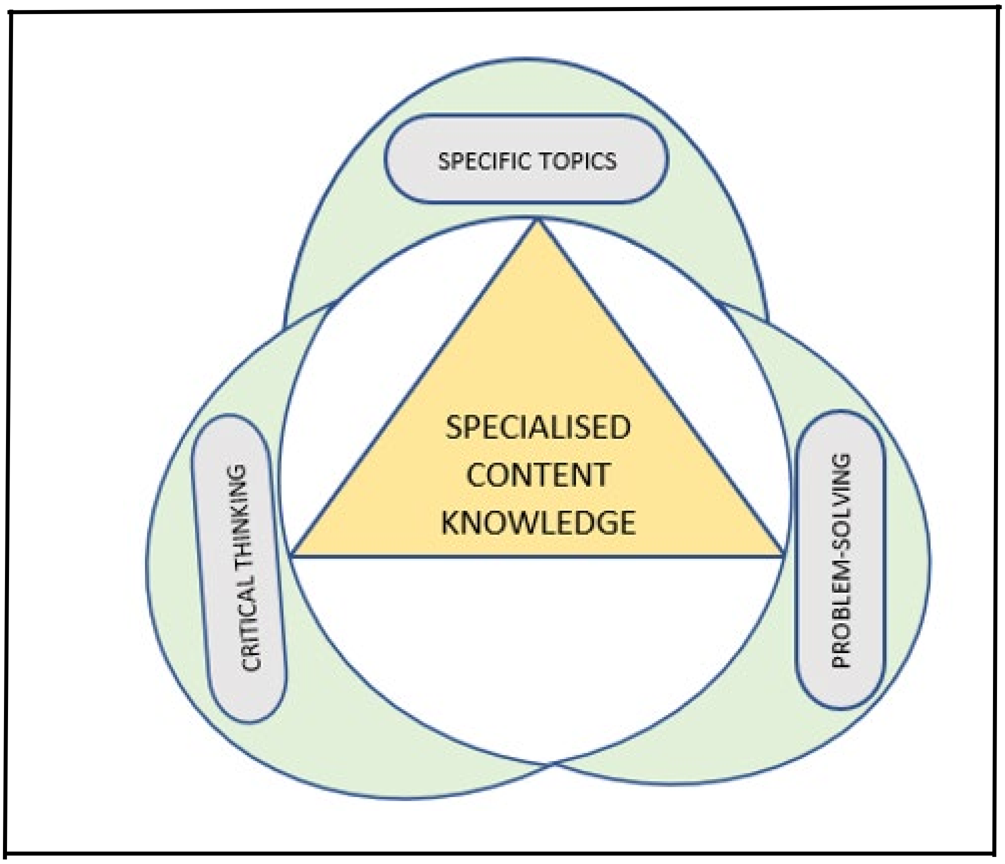
Knowledge at the mathematical horizon emerged as the knowledge of vertical and lateral curricula, applications of mathematics in different careers and the practical use of mathematics in life that was gained. This is consistent with theory (Ball et al. 2008) where mathematics teachers are expected to ensure that the mathematics content they teach fits well into the mathematics of the later world. These findings together created the understanding that the teaching of mathematics must be a knitted link of the past, present and future learning in mathematics grade by grade. Findings presented the learning of mathematics as a practical experience prevalent in workplaces and other settings. Informed by literature (Jacobson 2013; Hurrell 2013; Wineburg 2016) SMK in the form of knowledge at the mathematical horizon is mathematics founded and linked to the broader mathematics territory, which relates to the application of mathematics in life and the use of horizontal and vertical curricula in teaching mathematics. In this regard, mathematics teachers are generally motivated to make connections between topics and establish links within topics to foster coherence in their teaching and through understanding of the use of mathematics to develop quality instruction. However, although knowledge at the mathematical horizon is well distinguished from other forms of mathematical knowledge domains, findings seem to suggest that this is the mathematical knowledge domain whose boundaries of mathematical knowledge are not well defined insofar as it relates to the application of mathematics in life. Which mathematical life? When? And why? Further studies may be needed to set clearly the parameters for this knowledge domain. The FET mathematics teachers investigated also gained specialised content knowledge.

Specialised content knowledge (SCK)

The FET Grade 12 mathematics teachers experienced specialised content knowledge as the knowledge and skills needed for teaching particular mathematics content to specific learners. Results indicated that this kind of professional knowledge represents the knowledge of what learners bring to their learning (preconceptions and background knowledge) which mathematics teachers need to manipulate in order to craft effective instruction. Findings indicated that this is specialised content knowledge encompassing what both teachers and learners know about specific content and critical thinking and problem-solving which relates to the manner in which teachers correctly explain mathematical ideas and concepts (Ball et al. 2008). Figure 7.7 illustrates SCK that FET Grade 12 mathematics teachers acquired from their professional learning.

Findings regarding SCK in Figure 7.7 reflect SCK as a technical engagement where teachers are more confined to the real job of teaching mathematics in their roles. From Figure 7.7 SCK is the knowledge of specific content and critical thinking and problem solving. Literature (Scheiner 2017) and conceptual framework (Hurrell 2013) argues that specialised content knowledge transposes mathematics from an ordinary to a professional nature where mathematics teachers are profession-specific in their roles. The next section discusses SCK in the form of knowledge of specific content and knowledge of critical thinking and problem-solving as shown in Figure 7.7.

Figure 7.7: Kinds of knowledge gained related to SCK



Source: Researcher (2021)

Knowledge of specific content

From research findings, the knowledge of specific content is recognised as the knowledge of specific mathematics concepts gained. This is the knowledge that the FET Grade 12 mathematics teachers gained through examining common errors that learners made in different topics, planning for specific topics with colleagues and identifying key facts and concepts for emphasis during teaching. This is in line with theory (Ball et al. 2008) and conceptual framework (Hurrell 2013) insofar as mathematics teachers need to know the mathematics, they teach beyond what their learners are expected to know. With reference to these findings, I argue that this is knowledge that distinguishes mathematics teachers from those who know mathematics but are not teachers of mathematics. Informed by literature (Carrillo 2013; Ball and Bass 2005; Speer et al. 2015), I perceive knowledge of specific content through these findings as what motivates mathematics teachers to know mathematics beyond the levels of their learners and to know mathematics and mathematics teaching beyond the common content knowledge. These teachers also reported gaining knowledge of critical thinking and problem-solving discussed in the subsequent section.

Critical thinking and problem-solving

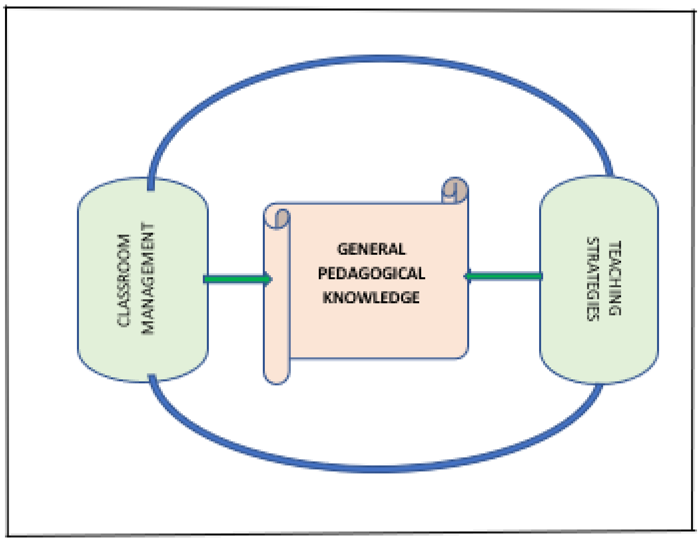
Developing critical thinking skills, guiding and giving learners clues in problem-solving, analysing mathematical story problems, identifying key words and phrases in mathematical questions and asking leading questions were kinds of professional knowledge that emerged as having been gained around critical thinking and problem-solving by the FET Grade 12 mathematics teachers in their roles. These findings present critical thinking and problem-solving as thought-provoking processes whose knowledge is vital for guiding learners to become independent and rational thinkers. This is consistent with theory (Ball et al. 2008) which implores mathematics teachers to solve mathematics problems correctly. Literature (Alcantra and Basca 2017; Firdaus 2015) suggests that critical thinking and problem-solving constitute knowledge that develops mathematics teachers' skills in analysing, testing, questioning, connecting and evaluating all aspects of a given mathematical problem. In this regard, critical thinking and problem-solving knowledge helps teachers to set their learners to think creatively, as asking questions by its nature promotes serious information processing (Olsher and Kantor 2013). Informed by theory (Ball et al. 2008) which encourages teachers to modify tasks to be either easier or harder, critical thinking and problem-solving are, therefore, central to mathematics teaching and valuable for quality instruction. However, teaching critical thinking and problem-solving continues to be a challenge for mathematics teachers who still experience content gaps and remain incompetent in their instructional roles (Pournora et al. 2015). Another domain of professional knowledge that FET Grade 12 mathematics teachers reported related to general pedagogical knowledge.

General pedagogical knowledge (GPK)

Grade 12 Research (Francis 2018; Guerriero 2017) emphasises that the GPK that FET Grade 12 mathematics teachers gained is vital for the facilitation of learners' learning and creation of suitable learning contexts. The findings indicated that the teachers gained GPK related to classroom management and teaching strategies. In the light of these findings, GPK remains a critical component of mathematics teacher knowledge given that learning does not occur in a vacuum and is an art requiring suitable teaching strategies.

Figure 7.8 presents the findings around kinds of knowledge gained related to GPK. To explain findings around GPK Figure 7.8 shows that the knowledge of classroom management and teaching strategies gained together constitute GPK. The blue lines linking the two knowledge domains connect them to create an environment conducive for effective teaching and learning characterised by general pedagogy. Supported by conceptual frameworks (Grossman 1998) general pedagogical knowledge remains necessary for every teacher in their roles to teach effectively. The following section discusses GPK related to classroom management.

Figure 7.8: Kinds of General Pedagogical Knowledge professionally gained



Source: Researcher (2021)

Pedagogical Knowledge of Classroom management

Findings regarding GPK of classroom management included what teachers needed to know concerning the activities and situations that promote the teaching processes. Indications from findings included management of time and classroom events, lesson pacing during teaching, creating a conducive learning environment, maintaining learner discipline, teacher-learner interaction, interpreting policies and making instructional decisions as forms of knowledge gained. These kinds of knowledge are fundamental for ensuring progress and safety in teaching. The knowledge revealed from these findings equipped the FET Grade 12 mathematics teachers with what conceptual frameworks (Grossman 1998) call 'practical knowledge' for enhancing the teaching and learning process. Literature (Ramadan 2014 and Grubb 2020) confirms that pedagogical knowledge of classroom management is basic for teacher success in their roles through effective manipulation of available resources to promote teaching. Therefore, GPK of classroom management is knowledge specific to setting the scene for instructional processes critical for every successful teacher in their roles. The following section discusses GPK gained related to teaching strategies.

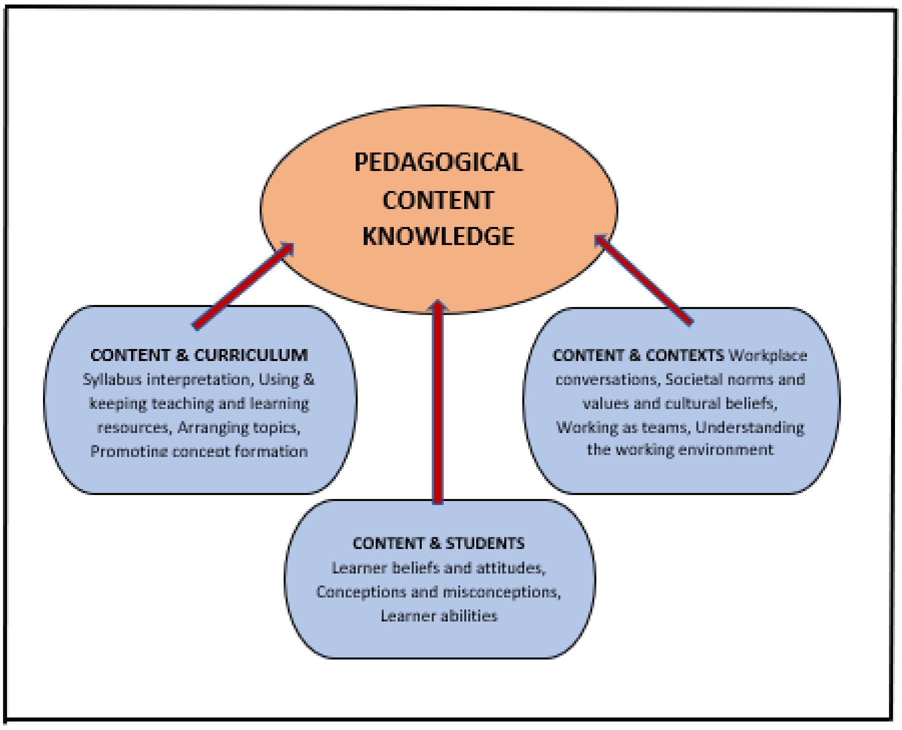
Teaching strategies

Teaching strategies emerged as structures, systems, methods, techniques, procedures and processes for the execution of instructional roles. With regards to these findings, the GPK domain around teaching strategies is what teachers needed to know to be able to motivate learners to learn, teach effectively drawing on principles of teaching and learning and justify their approaches and techniques for teaching. Informed by literature (Guerriero 2017; Goldstein 2015; Scheiner 2017), the GPK domain around teaching strategies is necessary for creativity and variation of approaches to teaching. For me, the knowledge bases created through GPK related to teaching strategies distinguished a teacher in his/her role as a leader whose task is to find a path for effective instructional and learning processes. Thus, from these findings, teachers as leaders in their roles, have the responsibility to influence learner learning through the structures, systems, methods, techniques, procedures and processes that they choose during the call of duty. However, irrespective of the value of GPK, FET mathematics teachers continue to have professional gaps in managing learning environments and promoting effective teaching (Cox 2019). PCK was another domain of professional knowledge that FET Grade 12 mathematics teachers reported to have gained from professional learning in their teaching roles.

Pedagogical content knowledge (PCK)

Findings indicated that FET mathematics teachers gained PCK related to content and curriculum, content and students, as well as content and contexts. The findings embraced PCK as the knowledge that assisted FET mathematics teachers to execute instructional processes effectively as it emerged as the technical ability for teachers to match theory with method based on an understanding of their learners' capabilities. These findings are consistent with Ball et al.'s (2008) model of mathematical knowledge for teaching where PCK has been enshrined as one of the requisite knowledge domains. The knowledge of content and contexts included in PCK is founded on the principles that any teaching cannot be implemented outside contexts, that is, the teaching of topics must be considered with due regard to prevailing situations and circumstances. Figure 7.9 indicates the forms of professional knowledge gained in this domain.

Figure 7.9: Kinds of PCK gained



Source: Researcher (2021)

From Figure 7.9, findings indicate that PCK reported by these teachers had three major pillars that subscribed to it. In this context, knowing the content one teaches and knowing the contexts in which it is taught gives the basis for teachers to plan for the instruction process while knowing the content, and curriculum gives the basis for teacher understanding of the material they need to teach. Knowing the content and students suggests understanding learners and what they bring to their learning context which together builds into PCK. The next section discusses the knowledge of PCK related to content and curriculum gained from professional learning through teaching roles.

Content and curriculum

Regarding the knowledge of content and curriculum, findings indicated that FET Grade 12 mathematics teachers gained knowledge related to syllabus interpretation, using and keeping teaching and learning resources, rearranging topics for teaching and promoting concept formation. These findings are based on theory (Ball et al. 2008) that mathematics teachers need to be familiar with the content that they teach, hence, the findings are unique to teacher roles and profession-specific to teachers. The findings generally speak to teacher understanding of their roles and the knowledge equips teachers for technical independence to manipulate the content to the advantage of their learners. Based on theory (Ball et al. 2008; Hurrell (2013), teachers should match the content to appropriate representations for instruction. I propose that mathematics teachers need to make the best use of their knowledge of association of concepts to provide effective instruction. In support, literature (Scheiner 2017; Carrillo 2013; Godino 2009; Dreher et al. 2018) shows that having a good grasp of content is not necessarily a sufficient condition for effective teaching, hence, teachers must uphold these PCK forms of knowledge. Therefore, on the basis of findings FET mathematics teachers can re-organise the topics in the curriculum to make their teaching and learning process easy, considering the resources available, and the content would be better understood by learners. The PCK related to content and contexts gained is discussed below.

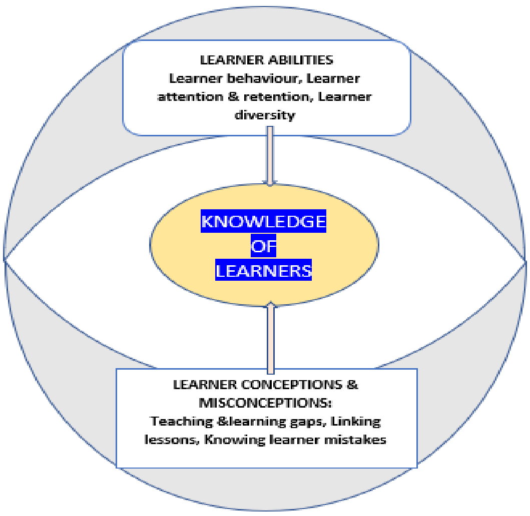
Content and contexts

The professional knowledge of content and contexts which emerged from the data related to knowing societal norms, values and cultural beliefs and working in teams. Understanding the working environment was also reported to have been gained from professional learning through teaching roles. The understanding of PCK through these findings is confirmed in theory (Ball et al. 2008) as what makes the learning of specific topics easy or difficult which learners of different backgrounds bring to the learning of different topics. While the findings appear alienated from mathematics teaching, the findings clearly show that teaching mathematics requires the use of practical and local examples. The instructional process calls for clear knowledge and understanding of the working environment to be able to identify effective examples comprehensible to learners during instruction. Borrowing from literature (Scheiner 2017; Celik and Guzel 2017), mathematics teachers should use powerful analogies, illustrations, examples and explanations without infringing on learners' personal life. As well, given that there are examples that may be taboo in certain communities, teachers need to have an understanding of their immediate communities. The findings exhibit through these forms of knowledge that PCK is the knowledge domain that distinguishes a content specialist from a pedagogue. The following section discusses the knowledge of learners gained.

Professional knowledge of learners gained

Findings related to knowledge of learners involved knowing learner abilities and knowing learner conceptions and misconceptions. Professional knowledge reported in this regard is basic for teachers to understand the learning levels of their learners and be able to scaffold them to get to their zone of proximal development. These findings form the basis for teachers to respond to individual needs of their learners and promote individual learner achievement. Figure 7.10 indicates the professional knowledge reported by FET Grade 12 mathematics teachers that related to the knowledge of learners.

Figure 7.10: Kinds of knowledge related to knowledge of learners gained



Source: Researcher (2021)

From Figure 7.10 the knowledge of learners is like the professional eye of a mathematics teacher which sees beyond the state of the learner and directs processes of instruction accordingly. Based on the findings, the knowledge of learners was crucial for teachers to plan and prepare for instruction. Knowledge of learner abilities is discussed next.

Knowledge of learner abilities

Research findings indicated that knowledge of learner abilities entails knowing about learners' behaviour, learners' attention and retention span, as well as learner diversity. Basing on conceptual frameworks (Grossman 1998) mathematics teachers must endeavour to increase learner engagement in their learning wherein knowing learner abilities is indispensable. Literature (Guerriero 2017) alludes to the need for teachers to understand diversity in learner abilities if they are to help individual learners effectively. Viewed together, the findings above suggest that this learning can assist mathematics teachers to determine materials that are accessible to learners and the extent to which they may engage the learners in teaching and learning activities. This is consistent with theory (Ballet al. 2008) as mathematics teachers require the knowledge of content and students for designing tasks and informing their instructional strategies. Therefore, the knowledge of learner abilities becomes critical as the business of teachers in their roles is to engage learners in tasks that promote their learning.

Learner conceptions and misconceptions

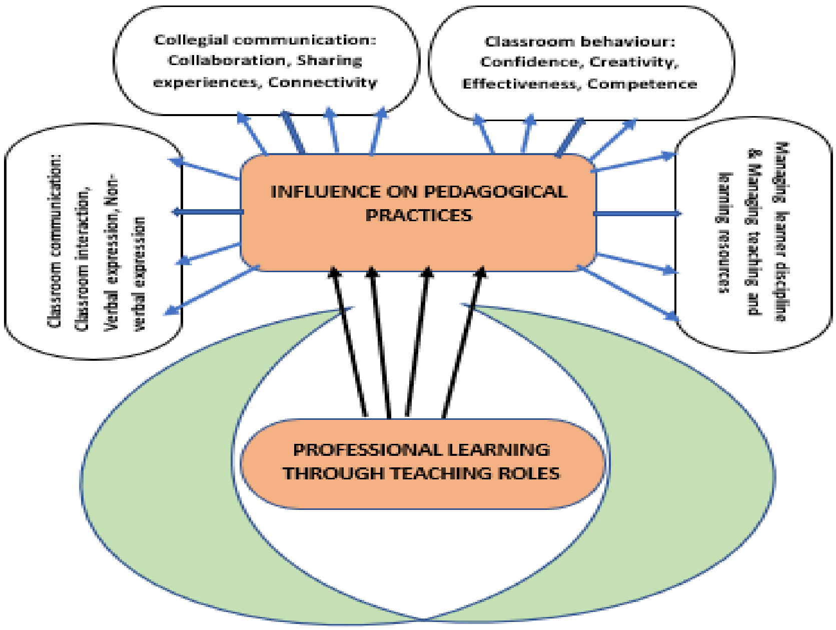
The knowledge of learners' conceptions and misconceptions was perceived as what learners bring to their learning in relation to what they are taught. Findings revealed knowledge of conceptions and misconceptions as knowing learning and teaching gaps, linking previous lessons to new lessons and knowing the nature of learner conceptions and misconceptions. Based on Hurrell (2013) and the theoretical framework (Ball et al. 2008), conceptions and misconceptions are the emerging and incomplete thinking of learners central to mathematics teacher knowledge of content and learners. The findings indicate that the success of any teaching process is in knowing learner conceptions and misconceptions (Scheiner 2017) as any teaching activity is an attempt to provide new knowledge and close created learning gaps from prior learning (Coutts 2017). Similarly, teachers are also bestowed with the responsibility to build concepts in learners from the known to the unknown, hence, the need to link previous lessons to new lessons (Wenk 2017; Campbell 2021). Informed by literature (Scheiner 2017), knowledge of learner conceptions and misconceptions is vital for meeting learner learning needs and enables teachers to recognize and overcome their teaching gaps during instruction. Thus, knowledge of learner conceptions and misconceptions represents what mathematics teachers need to familiarise themselves with to be able to reconcile learners' mathematical thinking and specific mathematical understandings (Hill et al. 2008).

The discussion above has shown that knowledge of learners that the FET Grade 12 teachers gained is a critical component of teacher professional knowledge which is strategic for executing relevant and effective lessons. The findings discussed, therefore, promote mathematics teacher knowledge to plan, prepare and teach lessons that are consistent with learners' learning needs, as well as instructional goals. Findings addressing how professional learning influenced FET Grade 12 mathematics teacher pedagogical practices is discussed next.

In what ways do the teachers say their professional learning influences their pedagogical practices?

Findings indicated that professional learning of FET Grade 12 mathematics teachers influenced their classroom behaviour and communication, ways of managing learner discipline and managing teaching and learning resources. Figure 7.11 below indicates how professional learning influenced these teachers' pedagogical practices.

Figure 7.11: Professional learning influence on pedagogical practices



Source: Researcher (2021)

Figure 7.11 portrays professional learning through teaching roles as a pot generating influence on pedagogical practices wherein it is released as boosters of teacher confidence, teacher creativity, effectiveness and competence, as well as communication. Professional learning generates influence related to skills in managing learner discipline and teaching and learning resources. These findings are discussed in turn below.

Professional learning influence on classroom behaviour

From the findings FET Grade 12 mathematics teachers' professional learning influenced teacher classroom behaviour related to confidence, creativity, effectiveness and competence. These findings are consistent with Cogill (2008) who encourages teachers to understand the work they do in a more independent and creative way. Literature (Lomba 2014; Mukeredzi and Nyachowe 2018; Sternberg 2013) shows that these qualities generate self- actualisation making teachers comfortable in their roles, especially when the influence originates from individual success in dealing with one's challenges. FET Grade 12 mathematics teachers' professional learning influence on their confidence, creativity, effectiveness and competence is usually a long-lasting milestone for motivating and regulating professional behaviour and making teachers independent and autonomous in their instructional roles. In light of these findings, such qualities from professional learning may help develop learner confidence and trust in their teachers during instruction.

Professional learning influence on communication

Professional learning influence on communication which emerged from this study encompassed classroom communication and collegial communication reflected in Figure 7.11.

Regarding classroom communication, Figure 7.11 indicates that professional learning gained by FET Grade 12 mathematics teachers influenced teacher-learner interaction and verbal and non-verbal expression in the classroom. Professional learning influence on classroom communication also reportedly enabled teachers to express themselves convincingly through detailed feedback that they started giving learners. Findings indicated that professional learning further influenced the teachers' collegial communication manifesting in collegial collaborations, sharing of experiences and connecting with each other in their roles. In agreement, Cogill (2008) encourages teachers through their communication systems to develop inter-personal relationships which aid their functionality in their roles. Findings indicated that these forms of communication among FET Grade 12 mathematics teachers boosted teacher-learner interactions and improved the co-ordination of activities in their roles. Informed by literature (Bosworth 2016; Goldsmith 2009; Nordquist 2019) the forms of communication in the classroom and with colleagues help to develop connections among both teachers and learners and boost teacher engagements with one another. This was further acknowledged by studies (Dollarhide 2019; Konen 2017; Khan 2019) which concurred that communication helps teachers to access each other's expertise. Hence, professional learning influence on communication is critical for building good working relationships among teachers and their learners, while at the same time creating interaction networks vibrant for effective teaching and learning. The following section discusses the influence of professional learning on managing learner discipline.

Professional learning influence on managing learner discipline.

Managing discipline among learners is a challenge that teachers in most schools are faced with and have difficulties to solve (Dhlamini 2017; Rossouw 2003). FET Grade 12 mathematics teachers reported having experienced professional learning which influenced managing learner discipline through class control, handling conflict among learners, tolerating learners' requests and unbecoming tendencies. This is in line with conceptual frameworks (Grossman 1998) which suggest that teachers should respect and understand learner deportment and background. Managing learner discipline in this regard becomes a critical responsibility for teachers who are entrusted by society with moulding learners' behaviour and ensuring successful teaching. This expectation places managing learner discipline central to the instructional processes for teachers in their roles (Alyzyoud et al. 2016). Literature (Moyo et al. 2014; Nene 2013) argues that once teachers manage learner discipline then they will have established learning platforms conducive for achieving instructional goals. Thus, managing learner discipline may minimise conflicts among both teachers and learners thereby creating 'harmony in difference' which is critical for successful instruction. Harmony in difference is a condition where teachers and learners live well together even though they could have varied opinions on some phenomena. Based on literature (Alyzyoud 2016), this situation is important in minimising learner timidity, intimidation and emotional frustration which directly influence their learning. Therefore, for the FET Grade 12 mathematics teachers, managing learner discipline plays out as a means towards achieving instructional goals and shaping learner characters for acceptance in the societies in which they live (Nene 2013). These teachers also experienced professional learning influence in the way they managed teaching and learning resources as discussed below.

Managing teaching and learning resources

Findings indicated that professional learning also influenced teacher management of teaching and learning resources such as policy documents, calculators, textbooks and maintenance of the asset register. Informed by theory (Ball et al. 2008) teaching and learning resources are 'tools of the trade' which teachers cannot do without. Literature (LINQ 2018; Shah 2018; Blandford 2003) considers the management of teaching and learning resources is one of the teachers' roles to ensure that their tools of the trade are available and accessible for their functionality. Viewed in the context of theory (Ball et al. 2008), managing teaching and learning resources ensures the availability of teaching and learning resources (Ebner et al. 2019) which enables effective instruction. From the findings, the FET Grade 12 mathematics teachers seemingly became aware of available resources and became responsible for them. Often teachers tend not to take care of the little teaching and learning resources that may be available to them while at the same time they complain that they fail to meet their teaching goals due to lack of resources. Thus, professional learning influence in managing the teaching and learning resources was consistent with challenges in schools regarding the maintenance of available resources.

Professional learning of FET Grade 12 mathematics teachers in their roles as illustrated above influenced their pedagogical practices in relation to their behaviour and communication in the classroom, as well as management of learner discipline and teaching and learning resources. The study discovered that effective communication created positive experiences in the classroom while learner discipline encouraged learner obedience and respect. The management of resources was not often given attention albeit the teachers usually complained about lack of resources for teaching and learning.

ORIGINAL CONTRIBUTIONS OF THE STUDY

The study sought to investigate how FET Grade 12 mathematics teachers engaged in professional learning through teaching roles. It further examined different forms of professional knowledge the teachers gained from their learning and the ways the learning influenced their pedagogical practices. My study made five contributions related to policy and practice of mathematics teaching and to theory as discussed in turn below.

First, previous research on teachers' professional learning indicated that mathematics teachers learn through professional learning communities (Graven 2002; Chauraya 2013). This study found that FET Grade 12 mathematics teachers effectively professionally learn through teaching roles in two sites (in the school and in wider professional sites) through practice and in formal, non-formal and informal spheres of action (Reid's quadrants). It was also discovered that professional learning was a practical experience (Kelly 2006) that teachers engage in motivated by domains of influence which subsequently enables them to learn more about their work through transmissive, transitional and transformative modes (Fraser et al. 2007). However, this literature falls short of how the learning occurs for mathematics Grade12 teachers in their roles which is a major contribution of this study.

Second, my study found that workshops and seminars may not be helpful if they are imposed on intended beneficiaries as such workshops may not meet the teachers' instructional needs. It is generally understood that professional learning for teachers is realised through workshops and seminars (Guskey 2009; Kelly 2006; Sayed 2016) on aspects related to teachers' professional learning needs. My study discovered that the FET Grade 12 mathematics teachers studied preferred professional learning through teaching roles – in classroom practice and not through workshops and seminars organised by school principals and/or subject advisors. Arguments raised in literature (Mukeredzi 2015; Chikoko 2009) indicate that workshops are basically intended to promote teacher professional development, education quality and relevance to national policies in respective institutions. My study found that professional learning through meetings dominated by school principals and other instructional leaders was viewed unfavourably among mathematics Grade 12 teachers.

Third, my study found that social gatherings are important professional learning spaces for mathematics Grade 12 teachers in their roles, which spaces were previously overlooked. Through social gatherings, the study found that teachers gained knowledge related to how teachers manage mathematical problems and challenges through understanding norms and values of immediate communities and learner backgrounds. Such knowledge is significant as it influences teacher practice in teachers' roles. This is usually knowledge that mathematics teachers would not associate with their instructional roles yet the learning of mathematics hinges on the background of the learners socially and cognitively. From the findings, this study found that teachers previously did not consider seriously knowledge of learners which to a large extent affected their teaching and learning rapport with learners. Arguments raised in literature (Mkhabela 2008; Preston 2018) perceive social gatherings as platforms for interaction and trading of ideas from which teachers learn. This study revealed that social gatherings are conceived as 'boosters of social connectivity' between teachers, parents and learners where all parties collaborate towards intended educational goals. Through social connectivity, the teachers' practices were complemented and supported so that their teaching objectives could be realised, hence, the general assertion that education is a societal matter.

Fourth, with regard to theory, the MKT theory (Ball et al. 2008) adopted, albeit useful for analysing and explaining subject matter knowledge and pedagogical content knowledge, was found inadequate for this study to unpack data in answer to the second research question around the kinds of knowledge gained as it did not accommodate GPK and KOL. To complement it, I consulted some conceptual frameworks (Grossman 1998; Cogill 2008). The study, thus, suggests an additive model which combines MKT and conceptual framework to accommodate GPK and KOL, other vital domains of knowledge mathematics teachers need for teaching.

Lastly, combining specialised content knowledge (SCK) with other kinds of SMK seemed to undermine teacher specialisation which should distinguish FET Grade 12 mathematics teachers in their roles. From the findings of this study, another contribution relates to separating SCK from SMK as SCK is the knowledge central to making these teachers profession-specific in their roles. In this regard, SCK distinguishes between knowing mathematics and knowing the mathematics for teaching. This includes presentation of mathematical ideas, connecting mathematical facts and concepts and making contributions to the development of mathematics teaching. To complement this idea, Hurrell (2013) argues that SCK is the mathematical knowledge domain which empowers mathematics teachers to appraise or criticise mathematics content in textbooks and other sources. Hence, from this study SCK should be conceived as a separate mathematical knowledge domain for teaching, valuable in distinguishing mathematics teachers from other mathematical disciplines.

IMPLICATIONS BASED ON THE STUDY

Based on the findings, implications of this study are drawn from three contextual perspectives: professional development, theory and research.

Professional development

Professional learning through teaching roles offers space for teacher professional development. From the findings the nature of professional learning through teaching roles was characterised by domains of influence within spheres of action in school and out of school through the transmissive, transitional and transformative modes. For the FET Grade 12 mathematics teachers studied, professional learning through teaching roles was a way of connecting with colleagues and a source of inspiration through the sharing of experiences and good practices. Thus, I recommend that instructional leaders encourage and support mathematics teachers to engage in professional learning through teaching roles for their professional growth and, consequently, enhance their instructional roles.

Findings demonstrated that professional learning through teaching roles offered an alternative to continued teacher professional development (CTPD) instituted by the South African

Council of Educators (SACE) (SACE 2015) and the integrated quality management systems (IQMS) (DBE 2003) which apparently lost favour among teachers because of the demand for paper work and association with incentives. Therefore, rather than coerce mathematics teachers to learn from unpopular programmes, these teachers need to be encouraged to professionally learn from the various spaces offered by professional learning through teaching roles in their own ways and in their own time. Instructional leaders must create opportunities to promote such professional learning among their teachers.

Teacher professional learning through teaching roles emerged as a cost-effective but dynamic way of getting teachers to gain knowledge and skills necessary for their instructional practices. Literature (Boileau 2017) confirms that investment in informal learning is cost-effective. From this study, apart from the role it plays in improving learners' performance, professional learning through teaching roles further reduces the cost of individual teacher development which is associated with SACE's CPTD and IQMS. Again, it has generally been difficult to attract FET Grade 12 mathematics teachers to professionally learn in workshops and seminars because of time constraints and lack of interest in such workshops and seminars. Hence, professional learning through teaching roles offers a reasonable alternative for teacher learning. It is, therefore, important for the Department of Basic Education to support and promote professional learning through teaching roles for the professional growth of FET Grade 12 mathematics teachers by encouraging learning-in-practice and creating opportunities for teacher social interactions within and outside their schools. Teacher support and professional development can be done through the provision of time and resources and the creation of appropriate platforms.

Theory

The MKT theory which was used to analyse and explain kinds of mathematical knowledge teachers need for teaching was found to be inadequate as a lens for understanding the kinds of knowledge teachers gain through teaching roles. It was necessary to understand how mathematics teachers set the scene for and facilitated learning and understood their learners (GPK). These forms of professional knowledge which were not incorporated by MKT theory were unpacked and explained through conceptual frameworks (Grossman 1998; Hurrell 2013). I, therefore, recommend that the MKT theory be reviewed to include other forms of knowledge mathematics teachers need for teaching and/or be substituted by an additive model which takes into account all forms of teacher knowledge domains needed for the teaching of mathematics.

Implications for research

The FET phase in the South African education system consists of Grades 10-12 classes in schools. This study only involved 26 FET Grade 12 mathematics teachers in one educational district in one Province. While my sample of 26 was adequate for a qualitative investigation (Clarke and Braun 2013), the findings could be limited to the Grade 12 teachers and the context in which the study was conducted. I, therefore, recommend that a more comprehensive study be carried out including other FET Grades (10 and 11) to offer generalisable and more concrete findings. The use of focus group discussions, individual face-to-face interviews and photo-elicitation worked well for this study. However, on reflection, adding observation as another data generation instrument would have helped to strengthen the study given the ability of observation to describe existing situations making use of senses (seeing and hearing), thereby providing a picture of the phenomenon under scrutiny (Mukeredzi 2020). Further research should use more data generation instruments, including observation. This may also include testing the additive model alluded to above. Thus, I suggest that future research be conducted which could be longitudinal based on mixed approaches including experimentation and observation to ascertain how professional learning is experienced through teaching roles, what the teachers learn and how the learning influences the teachers' pedagogical practices.

CONCLUSION

The study revolved around how FET Grade 12 mathematics teachers professionally learn through teaching roles and whether or not the learning influenced their pedagogical practices. This major aim of the study was answered in a nutshell in this chapter. The chapter presented methodological and theoretical reflections where the research process was reviewed to establish its effectiveness. This chapter further presented a review of the study where brief summaries of each chapter were given to recapture what was covered and put into perspective the basis for the discussion which followed. The discussion which was structured in three sections according to the three sub-questions for the study provided summaries of findings, explanations and discussions. It emerged that FET Grade12 mathematics teacher professional learning through teaching roles generally occurred in both formal and informal spaces within the school and in wider professional learning sites. These teachers gained five kinds of mathematical knowledge for teaching which distinguished them from other professionals in their roles. The learning which was reported influenced FET Grade 12 teachers' pedagogical practices in terms of their classroom behaviour, communication, managing learner discipline and managing of teaching and learning resources. The findings indicated that professional learning through teaching roles was mainly realised through practice and in interaction. Professional learning through teaching roles was portrayed as a significant alternative to seemingly unpopular workshops and seminars and a worthwhile venture into teacher learning through collaboration and networking for teachers in their roles. This was summed up by one of my research participants, Teacher 21 during FF Interview 3 who said:

> *What can substitute professional learning for teachers? Nothing! Professional learning is what made me the successful teacher that I am. If I depended on what I learnt then, in University, I would be obsolete by now. Professional learning is about sharpening oneself all the time to remain consistent and up to date with the realities of changing times. This is necessary because the quality of an education system cannot be better than the quality of its teachers.*

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APPENDICES

APPENDIX 1: Data generation instruments

DUT
DURBAN
UNIVERSITY OF
TECHNOLOGY

INSTITUTIONAL
RESEARCH
ETHICS
COMMITTEE

INTERVIEW QUESTIONS FOR FOCUS GROUP DISCUSSIONS - SCHEDULE

PART 1 (First interview)

1.1 Please tell me the kinds of activities that you do as an FET mathematics teacher?

1.2 Tell me the activities that you do inside the school from which you learn something. Please tell me more. What kinds of things do you learn? In what ways does knowing that help you in your teaching?

1.3 Tell me about any professional discussions that you have with colleagues (a) in the school (b) outside the school. What kinds of knowledge do you gain from such discussions? In what ways does that knowledge help you in your teaching?

1.4 Tell me about activities that you do outside the school from which you learn. Please tell me more. What kinds of things do you learn? In what ways does knowing that help you in your teaching?

1.5 What do you think about teacher learning outside the school? Tell me about the learning that you do outside the school. Tell me about the kinds of knowledge that you gain.

In what ways does the learning help you in your teaching?

1.6 Tell me about the kinds of activities that you do in class from which you learn something. Please tell me more. What do you think about these activities? How does this help you in your teaching?

1.7 What are your thoughts about the way you teach? And mark learners work?

1.8 But what encourages you to learn from these activities?

1.9 What are your opinions about teacher professional learning? What do you suggest as helpful in teacher professional learning?

FIRST INDIVIDUAL FACE-TO-FACE INTERVIEWS - SCHEDULE

PART 1 (First interview)

1. Please tell me about your teaching history.

2.1 Please tell me the kinds of activities that you do as an FET mathematics teacher?

2.2 Tell me the activities that you do inside the school from which you learn something. Please tell me more. What kinds of things do you learn? In what ways does knowing that help you in your teaching?

2.3 Tell me about activities that you do outside the school from which you learn. Please tell me more. What kinds of things do you learn? In what ways does knowing that help you in your teaching?

2.4 Tell me about a day in your teaching life from the time you wake up to the time you retire at night.

2.5 Tell me about the kinds of activities that you do in class from which you learn something. Please tell me more. What kinds of things do you learn? In what ways does knowing that help you in your teaching?

2.6 Are there any activities related to your class work that you do which you have not talked about? Tell me about them. What do you learn from such things? In what ways does knowing that help you in your teaching?

2.7 Tell me about activities that you do in your department from which you learn. Please tell me more. What kinds of things do you learn? In what ways does knowing that help you in your teaching?

2.8 Tell me about activities you do in the school from which you learn. Please tell me more. What kinds of things do you learn? In what ways does knowing that help you in your teaching? But what encourages you to learn from these activities?

2.9 Do you sometimes meet with your colleagues in the department? Tell me the kinds of things you talk about. What kinds of knowledge do you learn? In what ways does knowing that help you in your teaching?

PART 2 (2nd INDIVIDUAL FACE-TO-FACE INTERVIEW) - SCHEDULE

This session will be based on photographs.

3.1 Choose photographs that you would like us to talk about.

3.2 Tell me about this photograph. Why did you choose it? What was happening in the photograph?

3.3 What did you learn from this activity? In what ways does knowing this help you in your teaching?

3.4 What motivates you in this activity?

3.5 What other things do you do by being a teacher? What do you learn from doing those things? How does knowing those things help you in your teaching? How do you benefit from your professional learning?

3.6 Are any challenges that you face in the teaching of mathematics at FET phase?

3.7 How do you deal with and overcome these challenges?

3.8 What do you suggest should be done to encourage professional learning among FET mathematics teachers?

APPENDIX 2: Ethical clearance letter

DUT
DURBAN
UNIVERSITY OF
TECHNOLOGY

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

14 August 2018

IREC Reference Number: **REC 163/17**

Mr N Shoko
P.O. Box 329
Elliot
5460

Dear Mr Shoko

Teacher professional learning through teaching roles and its influence on pedagogical practices: Experiences of Further Education and Training Mathematics teachers.

The Institutional Research Ethics Committee acknowledges receipt of your notification regarding the piloting of your data collection tool.

Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely,

DUT DURBAN UNIVERSITY OF TECHNOLOGY
2013 -08- 14
INSTITUTIONAL RESEARCH ETHICS COMMITTEE
P O BOX 1334 DURBAN 4000 SOUTH AFRICA

Professor J K Adam
Chairperson: IREC

APPENDIX 3: Gatekeepers' Letters

Gatekeeper Letter 1

Province of the
EASTERN CAPE
EDUCATION

STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES
Steve Vukile Tshwete Complex • Zone 6 • Zwelitsha • Eastern Cape
Private Bag X0032 • Bhisho • 5605 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)40 608 4773/4035/4537 • Fax: +27 (0)40 608 4574 • Website: www.ecdoe.gov.za

Enquiries: B Pamla Email: babalwa.pamla@ecdoe.gov.za Date: 06 August 2018

Mr. N Shoko

55 Robinson Street

Flat 6

Elliot

5460

Dear Mr. Shoko

PERMISSION TO UNDERTAKE A DOCTORATE THESIS: TEACHERS PROFESSIONAL LEARNING THROUGH TEACHING ROLES AND ITS INFLUENCE ON PEDAGOGICAL PRACTICES: EXPERIENCES OF FET MATHEMATICS TEACHERS.

1. Thank you for your application to conduct research.
2. Your application to conduct the abovementioned research in Ngcobo administrative area schools under the jurisdiction of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:
   a. there will be no financial implications for the Department;
   b. institutions and respondents must not be identifiable in any way from the results of the investigation;
   c. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;
   d. you will make all the arrangements concerning your research;
   e. the research may not be conducted during official contact time;
   f. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Strategic Management Monitoring and Evaluation;

building blocks for growth

Page 1 of 2

PGDP EASTERN CAPE 2004 - 2014

Ilanma eliqaqambileyo!

g. your research will be limited to those institutions for which approval has been granted, should changes be effected written permission must be obtained from the Chief Director: Strategic Management Monitoring and Evaluation;

h. you present the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 – 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis;

i. you present the findings to the Research Committee and/or Senior Management of the Department when and/or where necessary;

j. you are requested to provide the above to the Chief Director: Strategic Management Monitoring and Evaluation upon completion of your research;

k. you comply with all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you;

l. you comply with your ethical undertaking (commitment form);

m. you submit on a six-monthly basis, from the date of permission of the research, concise reports to the Chief Director: Strategic Management Monitoring and Evaluation.

3. The Department reserves a right to withdraw the permission should there not be compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE.

4. The Department will publish the completed Research on its website.

5. The Department wishes you well in your undertaking. You can contact the Director, Ms. NY Kanjana on the numbers indicated in the letterhead or email nelisa.kanjana@ecdoe.gov.za should you need any assistance.

NY KANJANA
DIRECTOR: STRATEGIC PLANNING POLICY RESEARCH & SECRETARIAT SERVICES

FOR SUPERINTENDENT-GENERAL: EDUCATION

Gatekeeper Letter 2

PROVINCE OF THE
EASTERN CAPE

DEPARTMENT OF EDUCATION

TITUS BUILDING, CORNER OF CHURCH & HIGH STREET, PRIVATE BAG X 214, NGCOBO 5050
REPUBLIC OF SOUTH AFRICA, ENQUIRIES: MR A T FETSHA Tel. No: 047-5481004; Fax. No: 047-5481257;
e-mail address atfetsha98@gmail.com

TO : **MR. NEEDYARMS SHOKO**

FROM : **DISTRICT DIRECTOR**

DATE : **08 AUGUST 2018**

SUBJECT : **PERMISSION TO CARRY OUT A RESEARCH STUDY IN CHRIS HANI EAST DISTRICT**

The subject above has reference

1. This correspondence serves to acknowledge receipt of your request to carry out a research in Chris Hani East District.
2. I hereby grant you permission to conduct your research in the district, in keeping and in line with the ethical consideration that one has to observe in the process of doing research.
3. I would appeal to you that, upon completion of your study, you will be of immense help and that your study will assist us in making informed decisions and also improve our performance in Mathematics teaching.
4. Please produce this letter to principals and teachers so as to authenticate your programme.

Wishing you all the success you need as you pursue your studies.

Yours in Education

Department of Education
DISTRICT DIRECTOR

AT Fetsha 0 -08- 2018
Chris Hani East District Director

Province of the Eastern Cape
Private bag X214, ENGCOBO 5050

APPENDIX 4: Permission letter to Gatekeepers

The District Director
Department of Education
Chris Hani East
Ngcobo
5050

DATE………………………….

Dear Sir

RE: Permission to carry out a research study in Chris Hani East District

I am a student pursuing a PhD study through Durban University of Technology. I am writing to seek permission to carry out a research in your District. The title of my study is ***"Teacher professional learning through teaching roles and its influence on pedagogical practices: Experiences of FET mathematics teachers"***. The purpose of this study is to explore what and how FET mathematics teachers learn through teaching roles. The study also seeks to discover the kinds of knowledge that mathematics teachers gain and how such knowledge shapes their practices.

I intend to interview 26 FET Grade 12 mathematics teachers regardless of gender and conduct 4 focus group discussions in the four clusters in the District. I hope to collect data between August 2017 and February 2018. The findings of the study will be made available to your office.

For more information, you may contact my supervisors whose contact details are below.

Dr Tabitha Mukeredzi and Prof Julia Preece
Adult and Community Education
Unit of Adult and Community Education
Faculty of Arts and Design
Indumiso, Midlands Campus, Durban University of Technology
Pietermaritzburg

I look forward to hearing from you soon.

Yours faithfully

Needyarms Shoko

APPENDIX 5: Letter of information

LETTER OF INFORMATION (Department of Basic Education: Eastern Cape Province)

Title of the Research Study: Teacher professional learning through teaching roles and its influence on pedagogical practices: Experiences of FET Grade 12 mathematics teachers.

Principal Investigator/s researcher: Mr. Needyarms Shoko (MEd)

Supervisor: Dr T. G. Mukeredzi (PhD). Co: Supervisor: Prof Julia Preece (PhD)

Brief Introduction and Purpose of the Study:

This study is intended to explore how FET Grade 12 mathematics teachers engage in professional learning through their teaching roles. The study seeks to understand what these teachers learn through their teaching roles, kinds of professional knowledge that they gain as well as examine how such knowledge impacts on their practice. Therefore, findings from the study will inform FET mathematics teachers' on-going professional development.

You have been chosen because you teach FET Grade 12 mathematics in your schools.

Outline of the Procedure:

Individuals who choose to participate in this study will be organised into focus groups where they will contribute to the study through discussions at identified centres in their locality while some will contribute through individual face-to-face interviews at their schools. From focus group interviews, some of the participants will be requested to take photographs depicting situations in which they learn. The duration of focus group discussions and face-to-face interviews will be approximately forty minutes to one hour. The study will take place between August 2017 and February 2019.

Risks or Discomforts to the Participant

There will be no risks and discomforts as proceedings will be done by consensus. Focus group discussions and face-to-face interviews will be taped to allow the researcher opportunity to concentrate on discussions.

Benefits (to the participant and to the researcher/s)

This study will provide an opportunity for you to be heard with regards to your perceptions on what and how FET Grade 12 mathematics teachers learn through their teacher roles.

The Department of Basic Education may find some of the information you give useful in guiding their efforts to improve teacher effectiveness and enhance learner performance. As researcher, I will use this information to publish articles and present my thesis.

Reasons why participants may be withdrawn from the study

You may choose to withdraw from the study at any time without any prejudice.

Remuneration

You will be paid R75, 00 allowance for your lunch and R50,00 transport for participating in focus group discussions.

Costs of the study

You are not expected to cover any costs towards the study. All the costs will be borne by the researcher.

Confidentiality

Data generated will be kept with the highest degree of confidentiality.

Information will be kept anonymous so that nobody can recognise you from the information that you will give. I will use pseudo names where necessary and all the information will be kept under lock and key.

Research-related injury:

There will be no research related injury to yourself as a result of the study

Persons to contact in the event of any problems or queries

Supervisors: Dr Tabitha Mukeredzi, PhD. Co Supervisor: Prof Julia Preece PhD

Tel: 076 2995 974 / 082 605 6401

TabithaM@dut.ac.za JuliaP@dut.ac.za

Researcher Tel: 071 291 8256 Email: needyarms@gmail.com

Research ethics administrator on 031 373 2375. Complaints can be reported to the Director Research and Postgraduate Support, Prof. S Moyo on 031 373 2577 or moyos@dut.ac.za